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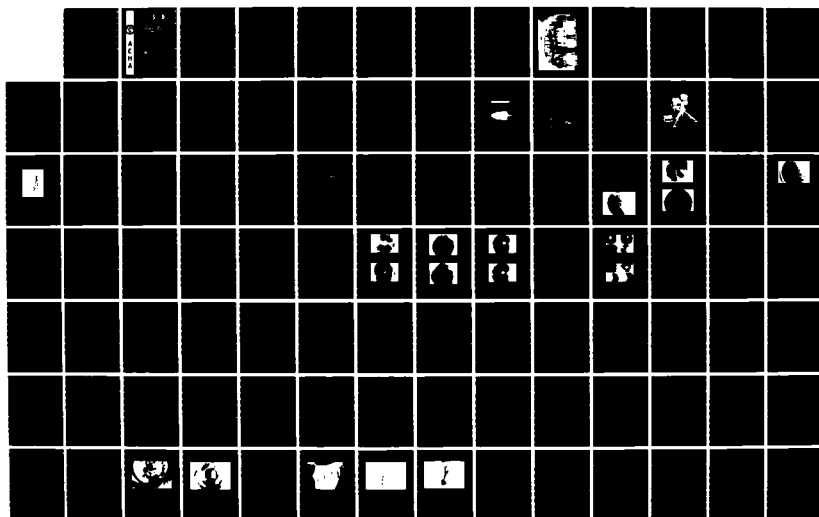
PROCEEDINGS OF THE SYMPOSIUM OF MEDICAL (OPHTHALMIC)
SURVEILLANCE OF PERS. (U) ARMY ENVIRONMENTAL HYGIENE
AGENCY ABERDEEN PROVING GROUND MD W G PITTS ET AL.
1982 USAEHA-25-42-0450-84

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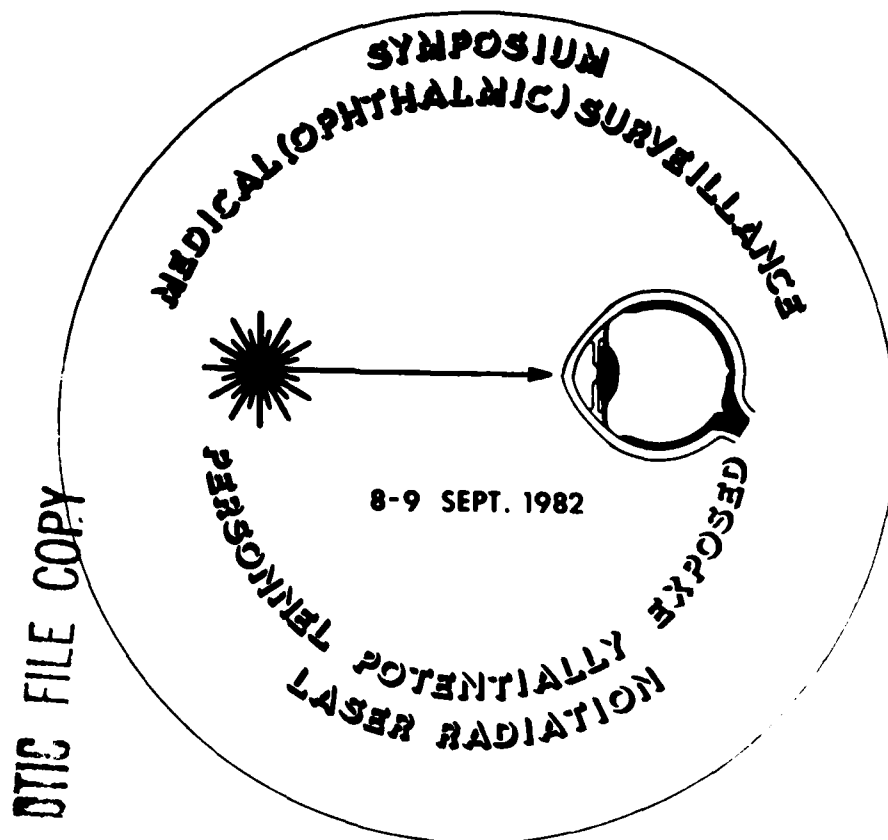
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**UNITED STATES ARMY
ENVIRONMENTAL HYGIENE
AGENCY**

ABERDEEN PROVING GROUND, MD 21010-5422

PROCEEDINGS



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Edited by Walter G. Pitts, LTC, MS
and David H. Sliney, DAC

NOTE: These proceedings were prepared from transcriptions of taped sessions of this symposium. Although some editing was performed, these proceedings were not prepared as written scientific papers.

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PREFACE

NOTE: The following introductory statement was prepared prior to the symposium and gives the scope and purpose.

1. INTRODUCTION.

a. Since the inception of the laser in 1961 and its use in the Army there has been difficulty in arriving at a policy on laser eye examinations. There have been those from the start who have argued that only a simple vision screening examination was warranted for medical-legal purposes. Others argued in favor of complete ophthalmic examinations since at first the laser presented an unknown agent. The ANSI Z136.1 Standard, Safe Use of Lasers, has relaxed recommendations for medical surveillance in each subsequent edition following 1973.

b. In the next 2 or 3 years, the number of military lasers being issued to field units will rapidly escalate. The total number of laser rangefinders (LRF) and laser designators (LD) will be in the tens of thousands. The potential for accidental exposure of the eye to hazardous levels of laser radiation will markedly increase, and the number of personnel potentially exposed will increase by an order of magnitude. Indeed, every combat soldier will be potentially exposed. This new laser environment requires that the Army Medical Department reassess the requirements for medical surveillance of Army personnel exposed to laser radiation.

2. PRESENT US ARMY POLICY.

a. In accordance with AR 40-46, Control of Health Hazards from Lasers and Other High Intensity Optical Sources, 6 February 1974; TB MED 279, Control of Hazards to Health from Laser Radiation, 30 May 1975 [reissued as TB MED 524, 30 June 1985]; and TB MED 506, Occupational Vision, 15 December 1981, personnel potentially exposed should receive preplacement and termination-of-laser-work ocular evaluations. Whenever a suspected or confirmed exposure of the eyes to hazardous levels of laser radiation occurs, an immediate ocular evaluation should be performed and (IAW AR 40-418, Medical Statistical Reporting, 16 August 1976) a MED 16 report filed within 5 working days of the incident. The ocular evaluation shall be performed by an optometrist, an ophthalmologist, or a physician skilled in funduscopy and biomicroscopy (slit-lamp evaluation) of the eye. Those personnel receiving a preplacement ocular evaluation should be incorporated in an Occupational Vision Program and receive a yearly vision screening examination with a multiphasic vision screener (e.g., Armed Forces Vision Tester or Ortho-Rater®).

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b. The following categories of individuals are considered to be in an occupation or assignment which may result in a significant risk of exposure to potentially hazardous levels of optical or laser radiation (IAW AR 40-46/TB MED 279):

(1) Individuals routinely using medium- or high-power lasers in any research, development, test and evaluation (RDTE) effort, where absolute protective measures are not feasible.

(2) Certain laser equipment, such as tripod-mounted, hand-held, or airborne LRF's, designators, or illuminators may be determined to present a sufficient hazard to operators and related personnel that such personnel may be required by The Surgeon General to be examined.

(3) Maintenance personnel routinely working with laser range-finders, illuminators, and designators.

(4) Operators and maintenance personnel routinely working with medium-power engineering laser transits, geodimeters, and alignment devices.

c. The minimum ocular evaluation should include the following:

(1) Recording visual acuity with correction (if below 20/40, check for improvement with pin-hole or \pm 0.50 D sphere and 0.25 D X-cyl).

(2) Dilating the pupil and examining the fundus carefully.

(3) Photographing, carefully describing, or drawing any lesion seen.

(4) Performing slit-lamp examination if the individual is potentially exposed to infrared (IR) or ultraviolet (UV) radiation.

3. PROBLEM AREAS. At present, two problem areas have been noted within the Army:

a. The heavy reliance of the examination upon subjective, descriptive, and qualitative measures (e.g., slit-lamp and ophthalmoscopic examinations) rather than quantitative visual function tests (e.g., Snellen acuity, contrast transfer, color plates) leads to variation in findings and interpretations by the examining eye specialists. The subtle nature of lenticular changes possible from IR or UV lasers and minute retinal lesions from visible and near infrared (IR-A) lasers may be indistinguishable from other natural changes in these structures or from changes induced by other etiologies. Two installations reported "possible laser-induced changes" in the eyes of soldiers. These findings arose from eye examination programs

following field tests at Fort Hunter Liggett, California and at Yuma Proving Ground, Arizona. Most, if not all, of these cases were later judged to be either normals, i.e., changes brought about by causes other than laser radiation, or caused by laser exposure received prior to working for the Government. These initial diagnoses demonstrated a shortcoming of ophthalmic examinations and the need for better training and education in this area. The USAEHA is presently developing a technical guide to assist Army eye specialists in performing such ophthalmic examinations, but some of the difficulties of defining "normal" and determining etiology will remain.

b. The numbers of soldiers who could warrant receiving these eye examinations could drastically increase in the near future if two-sided tactical exercises with LRF and LD become common. Additionally, future combat may expose essentially all soldiers to potentially hazardous levels of laser radiation. Based on current policy, this may result in such a large medical workload that ophthalmic examinations could not be performed on even a fraction of those requesting them.

4. OBJECTIVE OF SYMPOSIUM. The objective of the symposium is to discuss the following areas of concern in medical (ophthalmic) surveillance of personnel potentially exposed to laser radiation:

a. Which potentially exposed personnel should receive surveillance examination?

- (1) All personnel potentially exposed?
- (2) Only those with a significant risk of exposure?

b. What ophthalmic tests should be performed on the selected personnel?

- (1) Funduscopy and biomicroscopy (slit-lamp) examination by an optometrist or ophthalmologist?
- (2) Visual function tests such as spectral sensitivity, contrast sensitivity, etc., which can be administered by trained technicians?
- (3) Visual screening tests (e.g. Ortho-Rater, Armed Forces Vision Tester, Sight Screener) which can be administered by a trained technician?
- (4) Should different risk levels have different ophthalmic surveillance tests?
- (5) Can visual function tests replace ophthalmic examinations by eye specialists?

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c. When should the selected personnel be examined? and

- (1) Preassignment?
- (2) Termination of Assignment?
- (3) Periodic?
- (4) Should different risk levels have a different examination frequency?

d. Medical issues.

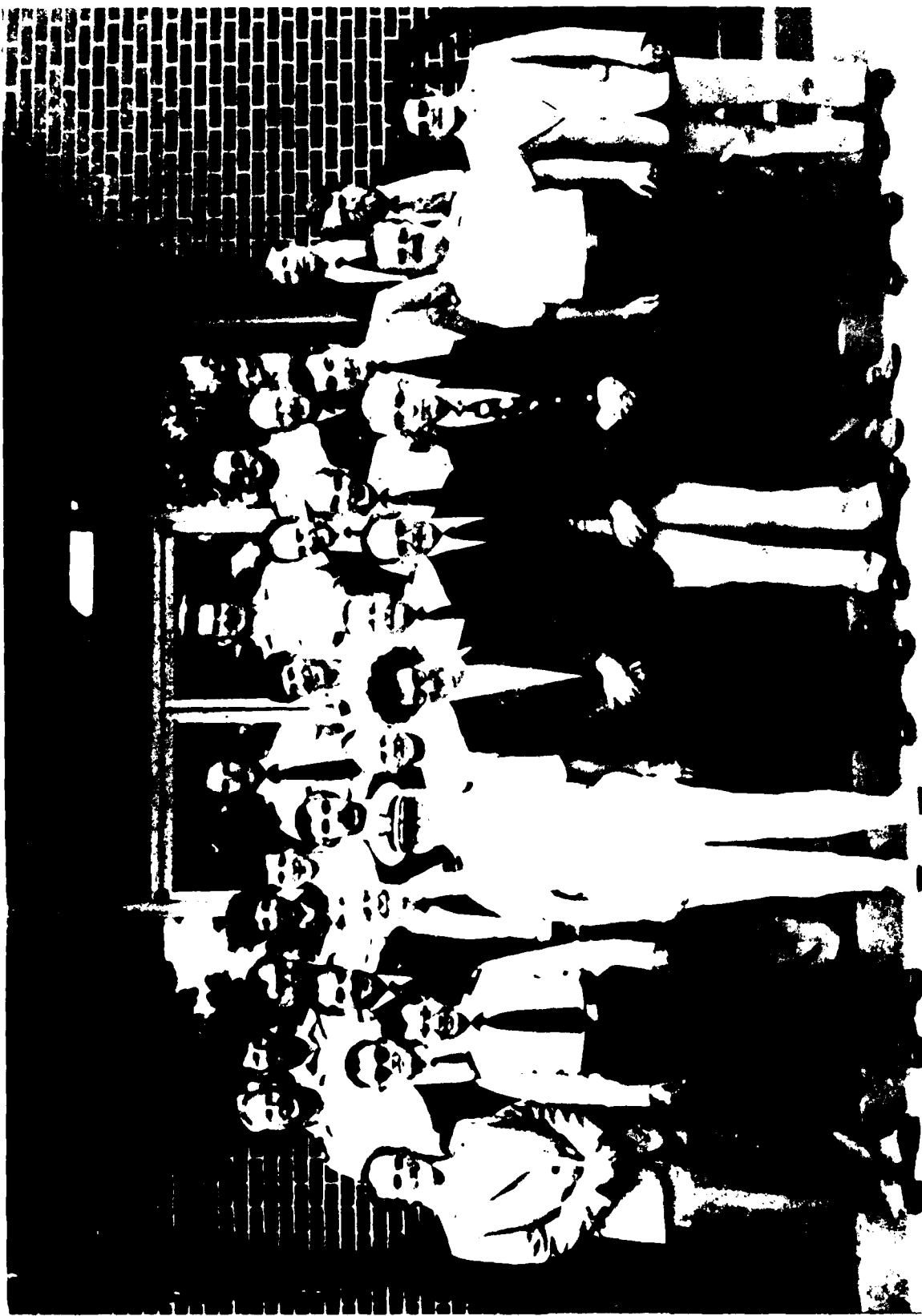
- (1) Are adequate numbers of ophthalmologists and optometrists available?
- (2) Can laser eye injuries be differentiated from other etiologies?
- (3) How can training be provided to health care providers?

5. REFERENCES. See Appendix A for a list of references and Appendix F for a bibliography.

6. ABBREVIATIONS. A list of abbreviations used is contained in Appendix B.

7. AGENDA AND INVITEES/ATTENDEES. The original agenda and a list of invitees and attendees are included as Appendices C and D, respectively.

8. PARTICIPANTS. The participants of this symposium are shown on the following group photograph.



PARTICIPANTS OF MEDICAL SYMPOSIUM ON OPHTHALMIC SURVEILLANCE OF PERSONNEL POTENTIALLY EXPOSED TO LASER RADIATION
8-9 SEPTEMBER 1982

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WELCOME TO USAEHA

COL Robert Wangemann, MSC
Commander
US Army Environmental Hygiene Agency
Aberdeen Proving Ground, Maryland

It is certainly a great pleasure for us to host this symposium this morning and tomorrow. The subject certainly is timely, although the general subject of medical surveillance certainly is not new even in terms of surveillance of laser workers. We do have a considerable amount of controversy involved in this subject, whether it is related to exposure to a particular chemical or physical agent or maintenance of the health of the worker. This is of prime interest to all of us always, and medical surveillance is but one tool that we use to evaluate how well we are doing in that area. We are obviously interested in the protection of the individual in terms of good solid work practices, engineering controls on the equipment or machinery with which he is working, and if necessary, personal protective gear such as laser protective eyewear or respirators. When we look at the effectiveness of these controls in terms of our surveillance program, we must choose whatever portion of that biological system that we can sample the easiest and best in order to determine the accuracy of our total overall control program. The basic questions still remain, "What do we do?" "How much do we do?" "How often do we do it?" and so forth. These are the issues and the questions that you will be examining today and tomorrow to help us (and probably others) address the issue of laser medical surveillance.

As Dave Sliney will address shortly in some detail, a lot of laser systems are being introduced into the Army for use by our soldiers. We need to have an effective program to monitor the exposures of these individuals to assure that the safety precautions we build into procedures or hardware are, in fact, necessary and do the designed job.

Just to satisfy myself and hopefully to enlighten those of you who may be strangers here, I would like to briefly talk about USAEHA, which is almost 40 years old. We will celebrate our 40th birthday next month. We were activated in 1942 as The Army Industrial Hygiene Laboratory to support the Army's manufacturing effort in support of World War II. Since that time, we have grown from a staff of about 9 to today's somewhat over 500 employees, about two-thirds civilian and one-third military, and have become the chief operating agency in the overall Army Preventive Medicine Program. This program includes not only occupational medicine, but also the health aspects pertaining to the Army's environmental quality programs. We support the Army worldwide, which means a considerable amount of travel for our employees. We basically function as a giant consulting firm. We have approximately 35 mission program areas within which we operate. Primarily, our work is out in the field at various Army posts and installations around the world. Our work here is limited to preparation of draft policy documents, review of various documents, proposed legislation,

proposed Federal rulemaking, and so forth, in support of the US Army Health Services Command (HSC). COL Rosenberg is here from our parent command, HSC. He supports COL Ranadive in the Army Surgeon General's Office by providing whatever assistance and support are necessary in these areas.

I would like, briefly, to show you how we are organized. If you have interest outside of the topical area of lasers, we have quite a collection of scientific and engineering disciplines that might be of particular interest to you. If you wish to visit another specialty, let LTC Pitts or Mr. Sliney know.

Under the Office of the Commander, we have five mission operating directorates plus the Directorate of Administrative Services. Administrative services are important since the product of any consulting firm is a report, and we publish approximately 1,500 technical reports each year. The DOEH, directed by COL John Cutting, is the main trunk of the Agency, which has grown since 1942. The DOEH is a co-host of this symposium. Under the DOEH are three mission divisions: the Industrial Hygiene Division, which is interested in the protection of the worker and his working environment; the Bio-Acoustics Division, with mission programs in both hearing conservation and environmental noise; and the Occupational and Environmental Medicine Division, which provides physician support, epidemiology support, occupational health nursing support, and, of particular importance to this symposium--optometry support. There are three optometrists on the staff of the Occupational and Environmental Medicine Division. In addition, the DOEH has two other mission program areas which are organizationally separate and distinct. One is Health Hazard Assessment, a new task within the mission of the Army Medical Department. Their task is to review all Army equipment within the research and development cycle to assure that proper engineering controls are built into this equipment to protect our soldiers. The other is the Occupational Health Education Office, with the mission of collecting resource information and occupational health education materials available throughout the world and making this information available to Army commanders and supervisors around the world to assist them in meeting their Occupational Safety and Health Act/Administration (OSHA) responsibilities in terms of employee education on the job.

The Directorate of Environmental Quality (DEQ) is our environmental engineering arm, with three divisions: Water Quality Engineering, Air Pollution Engineering Division, and Waste Disposal Engineering. These divisions support the Army and installation commanders in maintaining compliance with the several Federal environmental quality laws.

The Directorate of Radiation and Environmental Sciences (DRES) is your other co-host for this symposium. Under DRES are three missions divisions: Laser Microwave Division which has mission responsibilities in all matters pertaining to nonionizing radiation (i.e., lasers, RF, microwave, high intensity light sources, and magnetic fields); Health Physics Division which has a similar mission in all matters pertaining to ionizing radiation; and Pest Management and Pesticide Monitoring, which provides medical entomology consultative services to the rest of the Army.

The Directorate of Laboratory Services (DLS) at USAEHA also has three operating divisions. The Toxicology Division, with an applied toxicology laboratory (i.e., an industrial toxicology laboratory), examines and tests all varieties of compounds or materials that come in contact with the skin of the soldier. Sooner or later these substances make their way here for initial toxicology screening. There are two divisions within DLS which are primarily oriented toward chemistry: Organic Environmental Chemistry and Radiological and Inorganic Chemistry. I think our laboratory capabilities are as good as any under one roof in this country, and we maintain accreditation by all appropriate national and state accrediting bodies. We're very proud of the sophistication and the capabilities that we have within our laboratories and work very hard to maintain all the accreditations that are appropriate for any of our mission programs.

Lastly, we have a Directorate of Regional Activities which includes three Regional Divisions located at Fort George G. Meade, Maryland; Fitzsimons Army Medical Center, Denver, Colorado; and Fort McPherson, Atlanta, Georgia. These three regional divisions are relatively small and provide regional geographical support in the southeast, the west, and the northeast portions of the country. They provide a quick response capability to assist Army installations in their geographical locations.

That, in a nutshell, is USAEHA. We certainly are very happy to have you here. I appreciate your attendance and your interest in helping us solve a rather nagging problem: What do we do in terms of surveillance of personnel occupationally exposed, or potentially exposed, to laser radiation in the field or in the Army laboratory?

CHAIRMAN'S OVERVIEW OF THE PROBLEM

COL Manmohan Ranadive, MC
Office of The Surgeon General
Washington, DC

As Chairman, I would like to welcome each one of you on behalf of GEN Mitemeyer, our Surgeon General, and thank you for participating in this program. What better place to hold this symposium on laser surveillance than at USAEHA, which has played a tremendous role and contributed very heavily toward our understanding of health hazards from lasers and the protection of soldiers and Army civilians. In terms of welcoming all of you, a special thanks to those of you from our Uniformed Sister Services and to our distinguished colleagues from academic institutions in this country and, of course, a very special thanks to our distinguished colleagues from across the Atlantic.

The idea of this symposium was to bring together people from a number of different disciplines to discuss the subject of medical surveillance of laser personnel. These include occupational medicine, ophthalmology, optometry, health physics and radiation protection, vision research, and laser hazards research and evaluation. Mr. Sliney has introduced the attendees. The list is provided as Appendix D. Each attendee has received a book of resource materials with a lot of different references that have some relation to the subject matter.

Just this morning someone asked me: Why this symposium? What happened? Is there administrative pressure from above? Let me try to explain. Since the invention of the laser in 1961 and its introduction into the Army, we in the medical community have debated and discussed the ocular examination for laser workers. There have been some who felt that it ought to be a functional examination, whereas others very strongly believed that it ought to be a complete ophthalmological examination. Especially in the beginning, laser work constituted an unknown occupational hazard. There were unknowns regarding our ability to control the hazard and what effects laser radiation would cause in workers. Over the past 20 years, the Army's medical surveillance policies have changed. In the beginning, a team was sent from USAEHA to evaluate laser workers annually by both slit-lamp and ophthalmoscopic examinations. These studies were initiated by Dr. Bud Appleton and later, in 1977, reviewed by Dr. Hathaway. The present policies came as a result of that review. We accepted these policies as adequate until the past year when, on two separate occasions, as the consultant to The Surgeon General, I had to reconsider the soundness of these policies. What happened was related to the field test and evaluation of two separate Army systems having laser devices. According to our policies, we perform ophthalmological examinations of soldiers or civilians involved in such tests both prior to and after the test. The medical staffs at two different locations, involved with two different field tests, reported a high number of "suspected laser injuries." It is well known that bad news passes up the chain of command very rapidly,

much faster than even the word "fire." All of a sudden there was four-star general officer level interest in what was happening. Now, anytime there are reports of laser eye injuries occurring in large numbers, it simply implies to the line officers (who are nonmedics and, perhaps, do not understand the issue) that there may be inadequacies in the present safety program. They are obviously concerned about the health of our soldiers, particularly since laser devices, such as rangefinders and designators, are going to be increasing in number--perhaps 10,000 or so. But there is another issue. Over the past year or so there has been an increase in recognition of laser and directed energy radiation as a threat agent. When you consider this background, and when something happens that indicates our ability to protect our soldiers may not be as good as we thought it was, then you can imagine the sudden pressure to reevaluate what we are doing. Are we protecting our soldiers? Are our policies correct? From the point of view of The Surgeon General and the medical community, we could not afford to create the false alarms that had occurred with those two events. The credibility of the medical department was on the line. I contacted COL McDermott and COL Giroux and explained that we needed to do something about this situation. How could we improve the training of our clinicians that perform ophthalmic examinations? As we started thinking and talking about it, one thought struck us. This question assumes that the present medical surveillance policies are, indeed, appropriate and that the only factor that needs to be reviewed is the training of our professionals. In the past, one used to appoint a committee to solve the problem. Today, one holds a 2-day symposium, at the end of which a committee is appointed to try to solve the problem. So this is the purpose of this symposium.

My background is in occupational health and, from my position, I recommend to The Surgeon General policies in medical surveillance for both Army civilian and military employees. I am far from an expert in terms of the specific topic that we are discussing here--either as a clinician or as a biophysicist. What I would like to do at this point is to quickly review the present Army policy on medical surveillance of laser workers. Then I will review, in general, the concepts of an occupational health shield in the form of medical surveillance. I will forget the laser hazard and explain the question that we ask: Why do we have medical surveillance tests? This question can be addressed in light of the specific principles that are involved in medical surveillance. Basically, the current policies are contained in Army regulations and they cover the individuals routinely using medium-power or high-power lasers in any RDTE operations. Those personnel that operate certain laser equipment that is tripod mounted or hand held are considered essentially to be at high risk. Maintenance personnel having any involvement with hazardous lasers are at risk. Operators and maintenance personnel routinely working with Class 3 medium-power laser survey equipment also fall into the category of "occupationally exposed." The examinations are preplacement and at the time of suspected or confirmed ocular exposure to hazardous levels.

What is meant by examinations? We mean functional examinations and evaluation of structure. What are the problems we have had? It is very evident in the two incidents that I referred to that there are problems in describing and writing down what one sees with a slit-lamp examination or a fundus examination, in terms of intraexaminer variation. If we continue our present policies, the number of individuals that will require examinations will very easily outstrip our resources. The result is obvious: either we will examine only some, or we will examine no one. Should we be foolish enough to try and examine everyone, we would not be doing it right. Why do we perform medical surveillance? First, to determine whether an individual worker is physically and mentally able to perform his job. In terms of vision, certain standards exist, and evaluating visual function is appropriate. The baseline is a reference finding with which to compare future examinations, either after accidents or as a part of a surveillance program. Secondly, a surveillance program may be used to monitor the effects of a worker's exposure to a specific biological, chemical, or physical agent. In this regard, we are talking about the laser as a physical agent that can be monitored in the sense of a cumulative effect. But can laser medical surveillance function that way? Monitoring after an accidental exposure can answer the question: Did it actually happen? To detect earlier or subsequent defects resulting from accidental or inadvertent exposure to potentially hazardous laser radiation is another question. Can our present medical surveillance procedures detect subclinical effects of laser radiation so that we can take appropriate actions to prevent further damage from chronic exposure?

You really have to think in terms of cost effectiveness. This refers to physical fitness in terms of vision, and then the satisfaction of any legal or regulatory requirements. Some of the regulatory requirements are Army regulations, and we create certain regulatory requirements that everyone else in the field must satisfy. We must have cogent scientific reasons to establish these regulatory requirements. Thus, we examine all jobs to determine those that require medical surveillance. Essentially, when we have discovered high-risk individuals, we have had to work through the concern that I hope this symposium will be addressing--the suitability of surveillance tests or examinations. Anytime an attempt is made to select suitable tests or examinations, we must ask what we are trying to detect and whether we can detect this by the chosen test. Can we distinguish between acute versus chronic effects? What is the sensitivity of the test? It has been proven during the past year that the test, not the examiner, has caused us problems. With regard to examinations of personnel involved in field tests, we must ask if we can take purposeful action as a result of performing thorough examinations of individuals involved in these tests. We performed examinations prior to and at the completion of field tests, which, in theory, tell us whether safety procedures, protective devices, and individual training were adequate.

If one found a series of lesions in the postexamination, one could conclude that either the individual did not follow safety procedures, these procedures were not right, and so on. To review medical surveillance in this context, we must ask: How useful have these policies been in terms of introducing appropriate interventions to improve the safety of the soldier?

Functional tests can be applied to a certain extent for chemical exposures. Maybe these tests can be applied to a certain extent for radiation exposures. Some functional tests are presently not recognized. Should we be developing any such test? This is going to be a question of great importance to individuals like COL Whitmore, who have to be sure that whatever tests we recommend are indeed performed.

In terms of reviewing policies, we should ask whether we should be evaluating all persons, or only those with a significant risk of exposure. What test should we be performing? Just to provide a slight parallel, we will look at exposure to noise. At the present time the medical surveillance test used for potential exposure to high noise levels is audiometry--essentially an evaluation of function. If we could directly examine the organ of Corti as a surveillance test, I don't know how useful that would be. The same thing applies for exposure to a respiratory hazard. We perform pulmonary function testing, primarily as a medical surveillance test as part of a preplacement and, perhaps at a termination examination. Additionally, we may include a chest x ray. But a chest x ray, per se, as a means of visualization of that organ, is not used as a medical surveillance test. I think that some of these questions need to be addressed. Whatever policy we develop has to address these questions.

In summary, during the committee meeting at the end of this symposium, we must come up with the medical surveillance requirements for laser workers. These requirements have to be based on sound science and state-of-the-art testing; they have to be practical; we must be able to implement them; and they must be cost effective. They must take into account the best interest of the Army as an organization and, above all, they must contribute to the safety of soldiers and civilians.

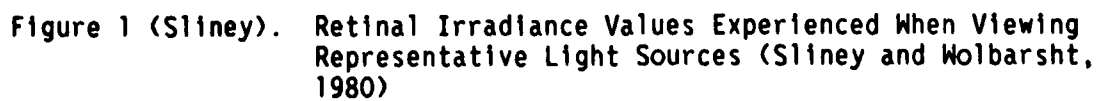
LASERS IN USE IN THE ARMY

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Figure 1 brings laser sources into perspective with conventional sources. It illustrates light sources which are imaged on the retina. Ultraviolet or far-infrared sources are not imaged on the retina. The normal ambient environment for the retina is about $10 \mu\text{W}/\text{cm}^2$. An extreme case for our visual environment is sunlight reflected off snow. This is about $100 \mu\text{W}/\text{cm}^2$. Levels well above that are normally from rather small sources, so that eye movements tend to distribute energy over the retina. Such sources as pyrotechnic flares, tungsten filaments, or welding arcs are not stared into for any length of time. In occupational environments, welding arcs are viewed through dark shade filters that reduce the light level to a comfortable value which falls in the middle of the normal retinal illumination range. Conventional frosted, incandescent lamps and fluorescent lamps are also in this zone of 10 - $100 \mu\text{W}/\text{cm}^2$.

If we look directly into the beam of a small 1 mW alignment laser, the type of laser most commonly used in industry, the illumination level on a small spot of the retina is about 100,000 to a million times greater than normal retinal levels encountered in observing outdoor scenes. Clearly, a laser is a source that is different from those which we have adapted into our evolutionary development. A 1-watt argon laser, the type used for treatment of retinal diseases, is another three orders of magnitude higher than the 1 mW alignment laser. Finally, the types of lasers that are used in military rangefinding and designation, about which we are concerned, can emit gigawatts of power for an extremely short time. Clearly, these lasers present a retinal hazard about which we shall hear in the next session. Another factor of importance from the safety standpoint is exposure geometry.

Most conventional light sources, such as the sun or very bright luminaires, are above us and we don't look directly into them. The geometry of the brow ridge and the high reflectance of the cornea at grazing incidence angles provide some protection to a light environment which is hazardous from a theoretical standpoint. But looking at a bright light directly is a different story. An example would be viewing either a welding arc or a laser. There are a few thousand people working with lasers in research laboratories in the Army and in other governmental and industrial laboratories. This group has been included, for the most part, in occupational vision programs since the beginning of laser development. Typically, these people wear laser eye protectors if they are working with rather dangerous lasers.



According to the degree of hazard, we group lasers into about four different categories. A Class 1 laser is basically an "eye-safe" laser. A Class 2 laser is safe for momentary exposures--at least as long as the blink reflex and aversion response to bright light (0.25 s). An example is a 0.5 mW helium-neon alignment laser. This is somewhat similar to this slide projector in terms of viewing risk (i.e., if you stared into the source for perhaps 15 or 20 minutes, you might develop a retinal lesion). Classes 3 and 4 lasers are more dangerous; serious eye injury can occur, even for momentary exposures. For these lasers, the blink reflex does not protect the retina as would occur if one looked into a 1 mW helium-neon alignment laser. Class 4 lasers can be a serious skin or fire hazard and may even be hazardous to view by diffuse reflection.

This hazard categorization aids engineers and safety specialists in deciding what control measures are to be used. In addition, this classification scheme has been used to indicate the need for medical surveillance or specific examinations for those personnel working with certain types of lasers. It is used in some standards such as ANSI Z136.1 and has been applied in present Army standards.

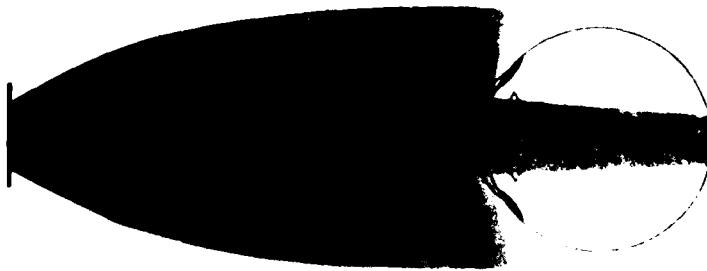
There are many new types of laser devices coming through the RDTE process. In both industry and the military, there is an increasing use of lasers in fiber optic communications. Infrared radiation from a semiconductor laser diode is transmitted along glass fibers to permit very high data rate communication. These Class 1 lasers are basically safe because they are enclosed, but maintenance workers who pull cables apart and look into them, particularly with a magnifying glass or an eye loupe, might be exposed to hazardous levels. These employee groups are, potentially, a very large population.

Hazard category limits or AEL's depend upon wavelength, because the different hazards vary with wavelength and are very significant. Class 1 AEL's are higher in the IR because ocular injury thresholds are lower than in the visible or UV. In the visible and IR, there are two viewing conditions and both can cause injury to the retina: direct intrabeam exposure and viewing a diffuse reflection (Figure 2). Most exposures of the soldier in the field will occur from viewing diffuse reflections. We have measured reflections from many types of targets and know that, basically, these are diffuse and are at levels far below safety standards. The real safety problem is from intrabeam viewing of a collimated reflection off glass or from direct illumination. In intrabeam viewing, laser light can focus to a tiny spot on the retina. This can result in a gain in irradiance from the cornea to the retina of about 100,000. This explains why the eye is so much more vulnerable in the retinal hazard region than is the skin.

We wouldn't normally think of Figure 3 as being a realistic combat scenario, that is, a laser directly illuminating a soldier. Tank rangefinders and LD's are used to direct heavy weapons like tank guns and artillery, so these lasers should not be directed at individual soldiers walking across a field. Therefore, there has not been a large effort to

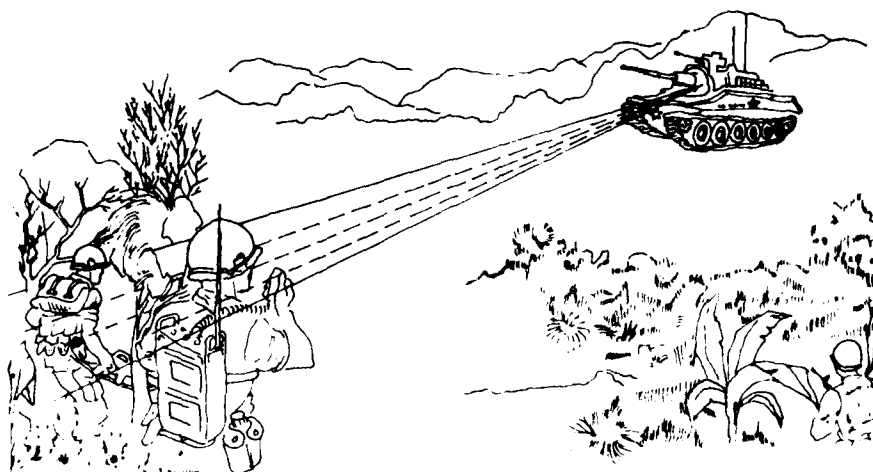


(a) VIEWING DIRECT LASER BEAM

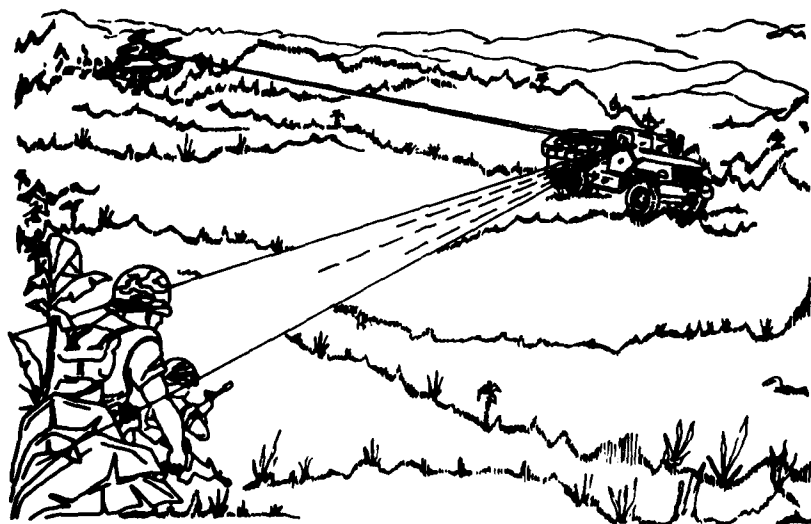


(b) VIEWING DIFFUSE REFLECTION

Figure 2 (Slaney). Viewing Conditions. Intrabeam viewing results in a "point" image, whereas viewing a diffuse reflection results in an enlarged image at close viewing distances.



INTRABEAM VIEWING



INTRABEAM VIEWING OF SPECULAR REFLECTION

Figure 3 (Slaney). Intrabeam Viewing in a Training or Combat Scenario

provide eye protectors for most infantry soldiers or to emphasize medical surveillance for these troops. These fire-control lasers are directed at bunkers, other tanks, and possibly aircraft. Therefore, people in aircraft or vehicles are typically provided with some degree of eye protection.

The type of laser that represents the greatest risk to the soldier is just now being put into Army service - the LD. Laser designators have been in research laboratories and involved in field tests by many nations over the past 10 years, but they are only now starting to be delivered to combat troop units.

The main use of lasers to date in the Army has been as tank LRF's. These rangefinders have used a ruby laser that emits a single pulse of very-high-power, very-short-duration laser energy. The beam is potentially eye hazardous out to several kilometers, but can cause very serious eye injury only if the beam is directed at a person within a few hundred meters or if someone views this source with an optical sight to a distance of 1500 m. A tank target sight may increase the energy entering the eye by 50 times, thus increasing the risk of serious eye injury. An LD is a neodymium laser device that emits near-infrared radiation at 1064 nm, which is largely invisible. The concept is to point the laser beam at a target such as a tank, thus illuminating a spot on the tank with IR radiation. You may recall that since the Korean War there have been IR heat-seeking missiles that "home in" on the hot exhaust of an aircraft. Some years ago, someone had the idea that if a tank doesn't have a sufficient heat signature, why not put a signature on it by pointing an IR beam at it? The reflected IR radiation guides in a missile, a cannon-launched projectile or a bomb.

The Army's present problem is training the users of these devices, because the hazard distance may be as much as 25 or 30 kilometers for the unaided eye, and these lasers may cause severe eye injury out to a few kilometers. Figure 4 shows one of these devices: the ground/vehicular locator laser designator (G/VLLD). At USAEHA, we have taken measurements on such lasers, characterized their beams, and set certain safety procedures for each device. There is a hand-held device which has a similar output but can be used only at closer ranges. As you can imagine, the pointing accuracy of the hand-held laser makes it difficult to use for precision designation. A hand-held rangefinder, the AN/GVS-5, is used by some observers. It is similar in size and weight to a pair of heavy binoculars. It emits an IR beam of 1064 nm laser radiation to obtain precise distance information for the observer. Because this device is a neodymium rather than a ruby laser, it is not as dangerous as earlier ruby laser models. It has a hazard distance of only about 2500 m. Thus, one could stand at a distance well beyond 2500 m and safely look back into the laser without eye protection. Some of us in my group have done just that.

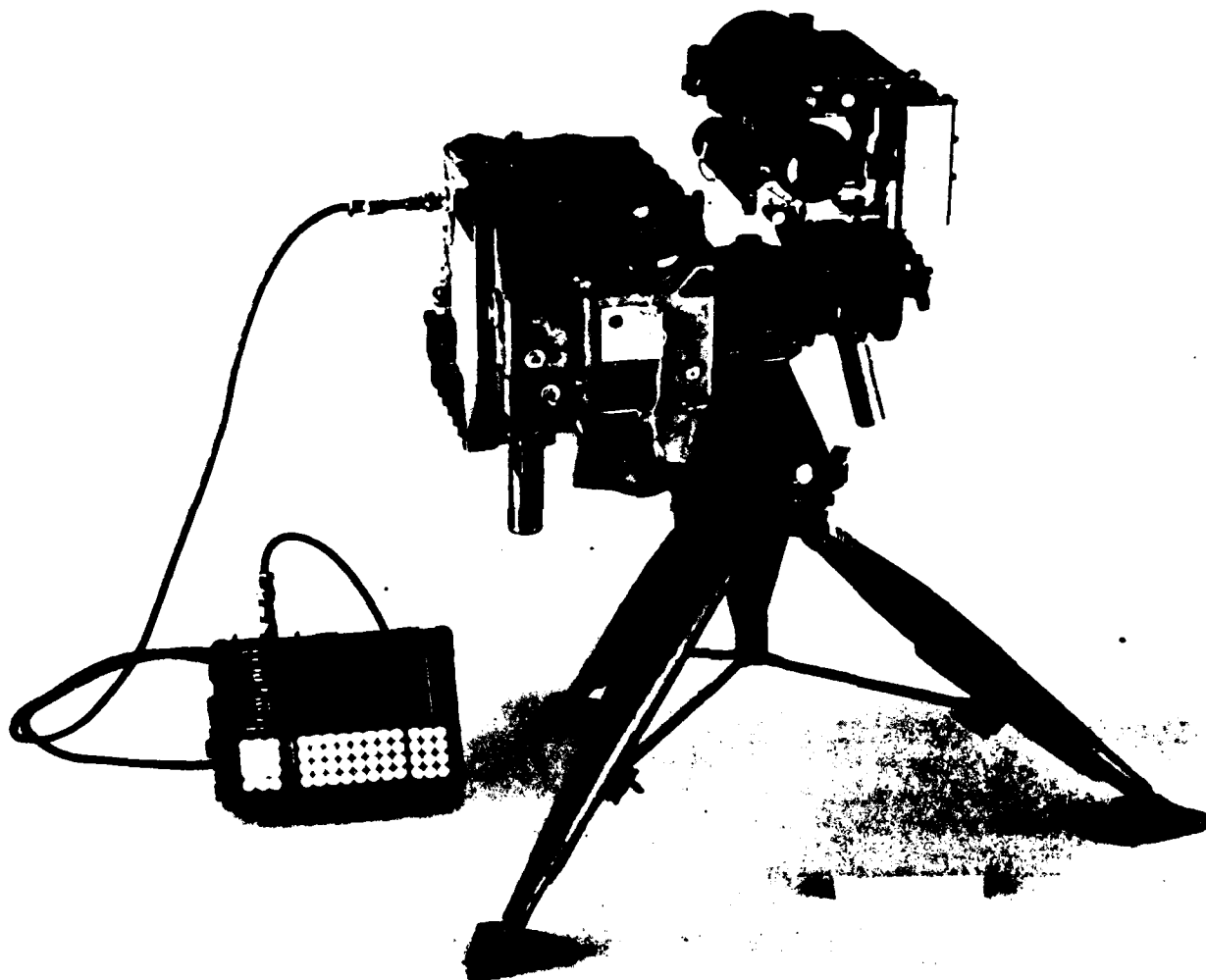


Figure 4 (Slaney). The G/VLLD, Tripod-Mounted

To summarize: There are different types of lasers, mostly in hazard Classes 3 and 4. Most of the newer lasers are neodymium (1064 nm), whereas some of the older tank LRF's are ruby (694.3 nm). They all pose potential retinal hazards and, since the Army wants to train personnel with these, certain training ranges have been established that are fairly protective. The G/VLLD has been installed in an armored vehicle, the Fire Support Team (FIST), where the beam is more likely to be at eye level (i.e., vehicle in defilade). People climbing over the vehicle would be at risk if someone pushed the laser button when they shouldn't. Similar LD's and rangefinders are in certain aircraft and can be found in all the services.

When lasers are tested, desert test ranges in the southwest are sought (e.g., Fort Huachuca, White Sands Missile Range, and Yuma Proving Ground). In these locations a large space exists, and often a mountain backstop will be present. Thus, if someone points a laser in the wrong direction, the beam is out of harm's way. Besides the range site selection, operational procedures are important. For example, in the early days of field testing, some test managers working with lasers were so worried about hazard control that they didn't trust the operating soldiers. They put up sandbag bunkers limiting the field of view, thereby they had only to control a limited range area. They limited entry to the area by use of military police guards. A mountain range served as a backstop so that the lasers fired in the restricted valley could not expose personnel.

A key aspect of field laser safety is to check the alignment of the laser device. If the laser operator doesn't know exactly where the beam is pointed and the beam is not aligned with the sight's crosshairs, some severe problems can result. We have discovered alignment problems in some prototype devices which had to be corrected. One way of checking beam alignment is to use an adjustable baffle. For example: An aircraft on the edge of an airstrip aims a laser through two apertures at a target. The apertures are oriented so that the beam can pass through them only if it is in a small cone angle which is defined by the target down range. In theory, any individuals located slightly off the beam path could stand there without eye protection while the laser beam is fired. By our rules, they wouldn't be allowed to get very close, but the point is that light travels in a straight line. It is possible to predict exactly where the beam will go. In laser safety, this is an advantage. With ballistic projectiles, the path is not straight; in addition, dangerous ricochets can result. We believe that the safety precautions we use with this equipment are now quite adequate.

There is no real reason for accidents. Furthermore, if one examines the probability of exposure, a further degree of safety is evident. For instance, if someone randomly fires a laser beam in the field, the chance that it will hit someone's eye is extremely remote. The beam has to be very concentrated to no greater than a meter or so in diameter to be dangerous, so the chance that someone will be in the beam's small cone angle in the field, and thereby exposed, is very low. This is precisely

why there have been so few accidents both in the military experience and in research laboratory work. In a research laboratory, the beam is typically the diameter of a pencil. One could compare a laser exposure to the chance of an eye injury from a pencil thrown across the room. The chance of either a laser beam or the pencil striking someone in the eye is remote. Accidents will happen, but the chance is fairly remote. The greatest hazard to people in industry and in research has been posed by the invisible neodymium-YAG laser beam. Where people didn't see the beam, accidents occurred. CAPT Wolfe will later review a number of accident reports and explain some of the effects observed.

One serious laser safety question we have encountered relates to perturbations of the beam. Figure 5 is a photograph of a cross section of a laser beam taken at about 1,000 m downrange. The effect is the result of atmospheric scintillation. We observe scintillation when we look at a star or at a point source at a distance. The light beam is broken into an irregular pattern. When you drive down a lonely road at night and see automobile headlights illuminating the inside of your car, you may observe this "dancing" pattern of light inside your car. This is due to optical turbulence. Unfortunately, it throws a statistical "monkey wrench" into the problem of setting any absolute "safe range" on a device. That is why we in the Army do not use the term "safe range." We call it a "nominal ocular hazard distance," or NOHD, indicating that it is a nominal distance at which we feel people are safe, but, mathematically, there is never a situation when you have absolutely no chance of injury at some distance beyond a hazardous distance. Furthermore, if someone beyond that distance looks toward the laser with a pair of binoculars, he may be at risk once again. Therefore, the basic concept behind the Army regulations pertaining to field laser safety is to terminate the beam inside the Government reservation and within controlled areas.

Although we are emphasizing lasers at this meeting, the same concerns we have about medical surveillance of laser workers apply equally well to people that maintain searchlights and work with bright light sources. Light sources such as 60-watt frosted incandescent lamps, low-pressure sodium lamps, and many fluorescent lights are so weak in terms of brightness and UV emission, that one could practically stare into these all day without exceeding present safety limits. But some improperly shielded, very high intensity illuminants (e.g., high-pressure mercury lamps, sun lamps, tungsten-halogen lamps or xenon-arc lamps) may pose a potential for retinal injury. That arc lamps are hazardous is certainly well accepted, because the Zeiss-manufactured Meyer-Schwickerath photocoagulator, once widely used in ophthalmology prior to the development laser photocoagulators, makes use of a xenon-arc lamp. It is just a matter of focusing this light energy onto the retina. Other lamps pose a potential for photochemical injury of the retina should one stare at the lamp for several minutes.

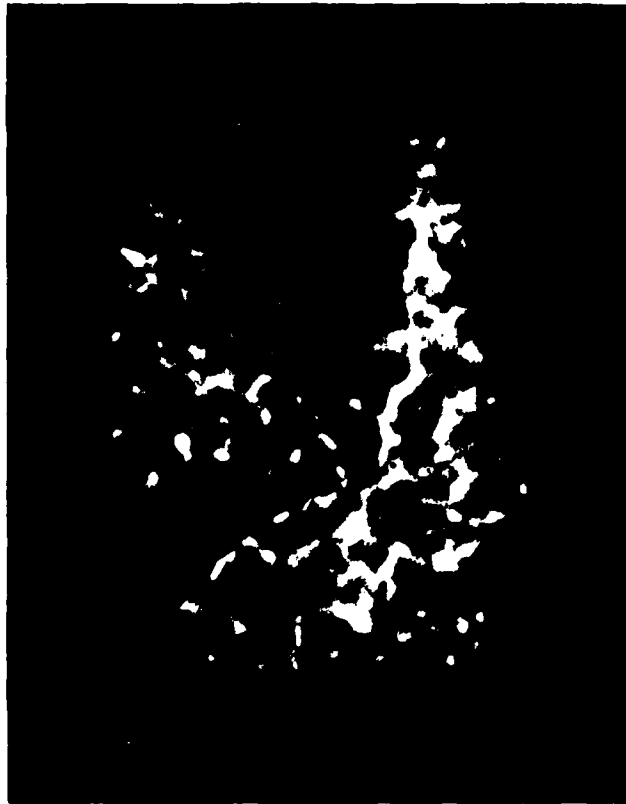


Figure 5 (Slaney). Cross Section of a Pulsed Laser Beam at 1,000 m

That finishes my prepared remarks. I do not see a value in explaining in great detail the many different types of current lasers. To summarize: The Army does use a number of different types of lasers. Most of them operate in the red and IR-A region of the spectrum. They are used in training, and most can cause severe eye injury if misused. Many safety procedures have been promulgated so that there is virtually no chance of someone injuring someone else. But if soldiers engage in "horseplay," or if someone points a LRF or laser target designator (LTD) (either maliciously or unwittingly) at a person and fires the laser, someone will be injured. To our knowledge, we haven't had any such incidents to date. We have had a lot of questionable cases where people thought they may have been "exposed" or even injured, but no clear-cut case has stood up to careful examination.

Reference

Sliney, David H. and Myron L. Wobarsht, "Safety with Lasers and Other Optical Sources," Plenum Press, NY (1980)

DISCUSSION

COL Rosenberg: To date, the Army uses lasers in training exercises involving the so-called integrated battlefield where problems have occurred and the possibility of additional difficulty exists. Here, personnel use hand-held or tripod-mounted lasers, while tanks or other tracked vehicles rolling over the terrain have built-in LTD's, and support aircraft are equipped with operational target designators. We may have the problem of people inadvertently looking up or aircraft coming in on a wrong azimuth, reflecting beams toward troops that are looking out toward this oncoming aircraft. It is with these scenarios that the Army Medical Department is concerned about the potential adverse effect.

Mr. Sliney: There are two approaches to training which are encountered in the field. Many officers of the combat arms want to provide very realistic combat engagement. For that purpose, the scientific community in the Army [specifically the Project Manager for Training Devices, (PM TRADE)] has developed a number of training devices, the most common being the MILES (Multiple Integrated Laser Engagement System). The MILES employs a gallium-arsenide simulator that works on much the same principle as an LRF or designator, but emits only a millionth of the other's energy so that the MILES laser is virtually "eye safe." Most MILES transmitters are at the borderline of being totally eye safe, but one should not stare into that source for a few minutes. Research from the Letterman Army Institute of Research (LAIR) indicates that a retinal change, or perhaps a retinal "lesion," may be possible. Other laser-training devices are used to simulate the laser beam from a LRF. You might ask: If you can train with those low-power lasers, why does the Army need more powerful beams? Well, first of all, the military LRF principle is to measure the distance to an uncooperative target. The enemy will not hold up a retroreflector to send the beam back to you, making it easy to measure the distance. That approach is followed in laser distance meters used by civilian surveyors. But to obtain a reflection off a very dull, diffuse surface of a tank, the LRF must emit a million times more energy. This implies an LRF which uses a dangerous type of laser.

So, if in a war game cooperative targets - little detectors on tanks etc., such as in the MILES concept - are employed, the more dangerous lasers are unnecessary. Whenever someone approaches with a request to train with dangerous lasers, we suggest investigating a technique to use the laser-training aids instead of putting protective filters on a thousand troops. We suggest filters over each of the lasers rather than over the eyes of troops. In a number of cases, we have been able to reduce greatly, or eliminate completely, the hazard distance of an LRF. An example is the tank rangefinder training system ESSLR (Eye Safe Simulated Laser Rangefinder), where a filter is placed over the output and a retroreflector is placed downrange. The amount of filter attenuation afforded is enough to make the LRF virtually "eye safe." But the problem with such an approach is that the gunner must have a direct hit on the retroreflector in order to receive a range return. This is not totally realistic, but it is "safe."

However, in some cases, the users say that the simulation is not good enough and insist that they must really fire at one another. What would happen then? Eye protection would be required for everyone. We have not ruled out such training, but we have simply said: "Let's really examine this first, since there are many potential problems if people do not 'get the word.'" There are always 10 percent of those who do not get the word," as the expression goes. It takes only one soldier with his goggles removed, not knowing of an active laser status, to be injured.

We had one case-in-point at the recent Fort Hunter Liggett tests, where one participant claimed a lens fell out of his goggles just as he was looking at a source. While this report sounds a little farfetched, it is not impossible. We conclude that a 100-percent safe scenario cannot exist if everyone fires lasers. One should first question if such training is necessary. Laser designators and rangefinders are for fire control and are used with live fire at targets. Two-sided live-fire is not used in training exercises. Laser guided missiles and cannon-launched guided projectiles each cost thousands of dollars. Training rounds do not exist, although apparently, every field unit will be given a few live rounds each year to fire. This raises the question of whether there is, indeed, a legitimate training need for two-sided laser engagements. Often the problem exists that combat troops have not adequately understood this new technology and, therefore, have a poor idea as to how the lasers should be employed in training. They are worried about safety and, at the same time, do not fully understand the safety implications of what they can really do. These questions continue to arise, but so far there has been no case where live lasers could not be used when legitimate training needs existed. The door is not closed, but the training staffs are encouraged to find another alternate procedure. If training filters are employed, there is always a chance that one of the filters will be broken or not be properly installed. We must recognize that, eventually, the Army will experience some valid laser injuries. In such cases there will be little question whether the injury was caused by a laser.

One anecdotal story that I have been unable to corroborate absolutely is of interest in this regard. A few years ago, a combat unit in Europe believed that it would be a great idea to fire its tank rangefinders at one another. They applauded themselves for this approach, because they used the LRF to simulate the main gun. They reportedly had several exercises. When higher headquarters and the medical authorities found out about this, they ordered it stopped. Surprisingly, they could find no injuries. This is an illustration of how the real laser risk is fairly minimal. The laser beam is so collimated that the likelihood of a direct shot right in the eye is fairly small, even when soldiers are firing at one another. Of course they were not intentionally trying to look at one another in that case. Hence, we do not expect a large number of injuries in training, but a few can be expected from horseplay, as with any hazardous device in the hands of troops.

OPHTHALMIC EFFECTS OF LASERS - RESEARCH KNOWLEDGE

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I will give a brief overview and introduction to CAPT Wolfe's lecture. We are from LAIR - part of the US Army Medical Research and Development Command. We have been involved for some time in laser bioeffects research, not only as an in-house activity, but also as support for several contractual efforts. Some of those efforts are presented in this forum today. I want to begin where Dave Sliney left off.

Lasers have now been around for 20 years. Their use in the military is beginning to proliferate. The Ground Laser Locator Designator contains a repetitively pulsed neodymium laser, operating at 1.06 microns; ruby and neodymium LRF's have been in the field for some time now. The MILES (Multiple Integrated Laser Engagement System) is a laser training device which uses a small gallium arsenide (GaAs) laser diode and mounts on the M16 rifle. The point to be made is that a large number of lasers are going to be in the field. The MILES will be used by a large number of soldiers. Its use requires pointing or directing the laser radiation at other soldiers down range. It is a relatively safe device. At significant ranges, the beam irradiance falls well below the maximum permissible exposure. Laser safety may be a problem in the depot where one has to perform adjustments or other maintenance procedures on the device at close ranges. The MILES does represent a first for military laser use, in that radiation from a large number of MILES will be directed or pointed at individuals. There are other MILES that are being developed to simulate other weapon systems. This indicates the variety of military laser devices which will be used in training. Fortunately, as Mr. Sliney pointed out, we have a good laser safety record to date. However, with the increasing numbers of fielded military systems, that record could change in the near future. This might impact on the sense of this meeting.

A cross section of the optical system that is of concern to this meeting, the human eye, is shown in Figure 1. The human eye has been, and probably will continue to be, the most important optical sensor on the battlefield. Since laser radiation is well collimated, the laser light collected by the eye and transmitted by the ocular media is focused on a very small spot on the sensory retina. Because of the focusing of visible and IR-A laser radiation on the retina, the eye is susceptible to injury. The laser bioeffects data base, which has been established over the last 20 years, describes the ocular susceptibility. We continue to enlarge that data base. Dose response relationships depend on a large number of factors such as pulse duration, PRF, retinal irradiance diameter, and wavelength. The emission characteristics of military laser systems cover a wide range of wavelengths and exposure conditions. As an example, the emission of the MILES consists of a train of 20 nanosecond (ns) pulses that are both amplitude and frequency-modulated such that "words" or "messages" can be transmitted and interpreted. This, indeed, is a unique ocular stimulus.

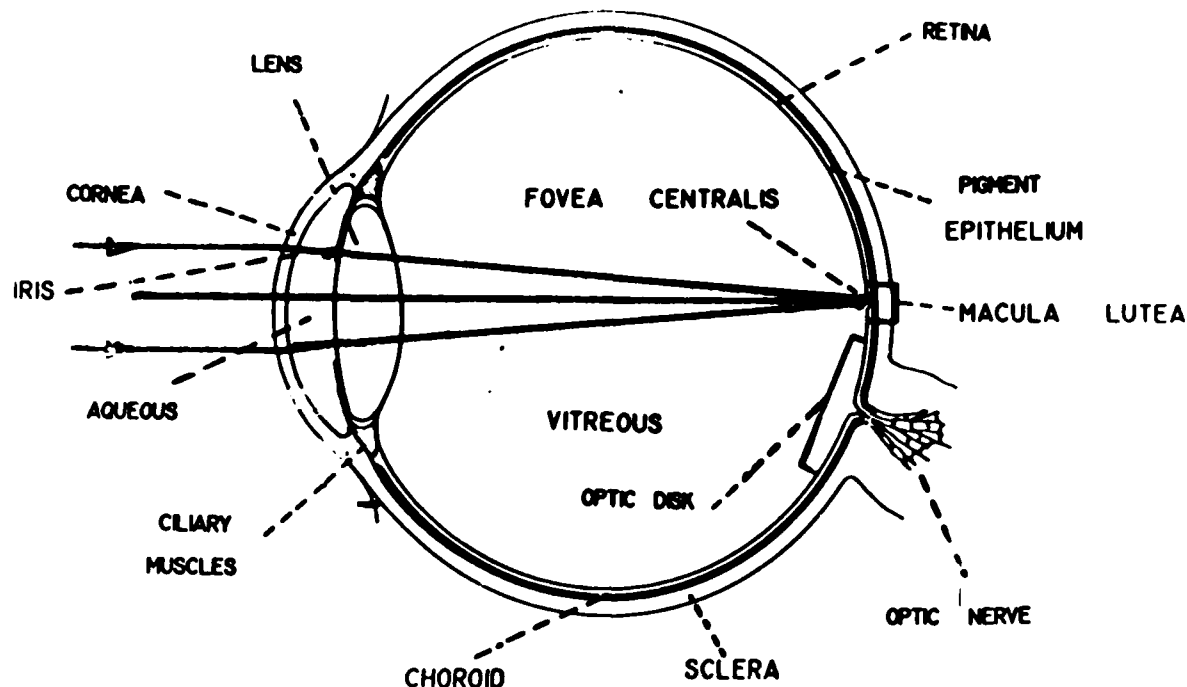


Figure 1 (Stuck). Schematic Cross Section of the Human Eye

The ocular response to laser radiation depends on the wavelength and exposure conditions. I will briefly review some of the exposure conditions and concomitant trends in the experimental data that impact upon the hazard. For visible and IR-A laser radiation, ocular injury may range from vitreous hemorrhage, retinal hemorrhage, retinal burn (i.e., an ophthalmoscopically visible lesion) to a "flash" effect, depending on the dose. Exposure to a visible laser pulse may produce a flash effect that may not produce any visible pathology in the eye but temporarily disrupt functions. These effects are currently being investigated in our laboratory. For infrared laser radiation which is not transmitted by the outer ocular media (i.e., carbon dioxide and chemical laser radiation), ocular injury may range from a corneal descemetocoele, corneal opacity/burn, to a pain sensation in the absence of a visible lesion.

Throughout the years, dose response relationships have been established for a wide range of laser exposure conditions. For visible and IR-A laser radiation, the data base has been established primarily in the rhesus monkey eye. A collection of data for exposures of a minimal retinal irradiance diameter (from 20-50 microns), is shown in Figure 2. The data for exposure durations greater than 1 millisecond (ms) in the upper curve were obtained by using an argon laser, radiation at 514.5 nm; whereas, for exposure durations less than 1 ms, frequency-doubled neodymium laser radiation at 532 nm was used. The data points in Figure 2 represent the ED_{50} for the production of an ophthalmoscopically visible lesion 1 to 24 hours after exposure. The experimental procedure uses the ophthalmoscope to examine the exposed retinal site. The experimenter places an array of exposures in several rhesus monkey eyes over a range of doses and, upon ophthalmoscopic evaluation, says "Yes, I see a lesion" or "No, I don't," at each exposure site. These results are statistically treated to determine the exposure dose (ED) at which a lesion is observed 50 percent of the time (i.e., ED_{50}). In Figure 2, the range of exposure duration extends from a picosecond (10^{-12} s) duration to as long as 1000 seconds. Figure 2 also shows data obtained in other laboratories. The ED_{50} for a retinal burn also varies as a function of the retinal irradiance diameter. In the typical field situation, we primarily would expect the viewer to see a point source, and experience a minimal retinal irradiance diameter. Figure 3 shows large image size data. As you increase the retinal irradiance diameter, the retinal radiant exposure required to produce a threshold dose decreases, and this decrease is noted throughout a wide range of exposure durations from 30 ns to 1 s. That fact is sometimes misinterpreted. It does not mean that less energy enters the eye for the larger lesion thresholds. For minimal images, we express the ED_{50} as the total intraocular energy: the energy that can be measured on the cornea that will enter the pupil. This datum is for a minimal spot size, a 317-micron spot and a 775-micron spot. As the retinal irradiance diameter increases, the total energy into the eye must increase.

There are obvious structures in the retina: the macula and extra-macular areas, the optic disc, and the retinal vasculature. In one experiment, numerous exposure conditions were varied to compare the difference in dose for macular and extra-macular exposure sites, and also to view the difference in dose required for different corneal irradiance diameters. Thus, we must conclude that there are many parameters to be considered when discussing the dose required to produce even ophthalmoscopically visible lesions.

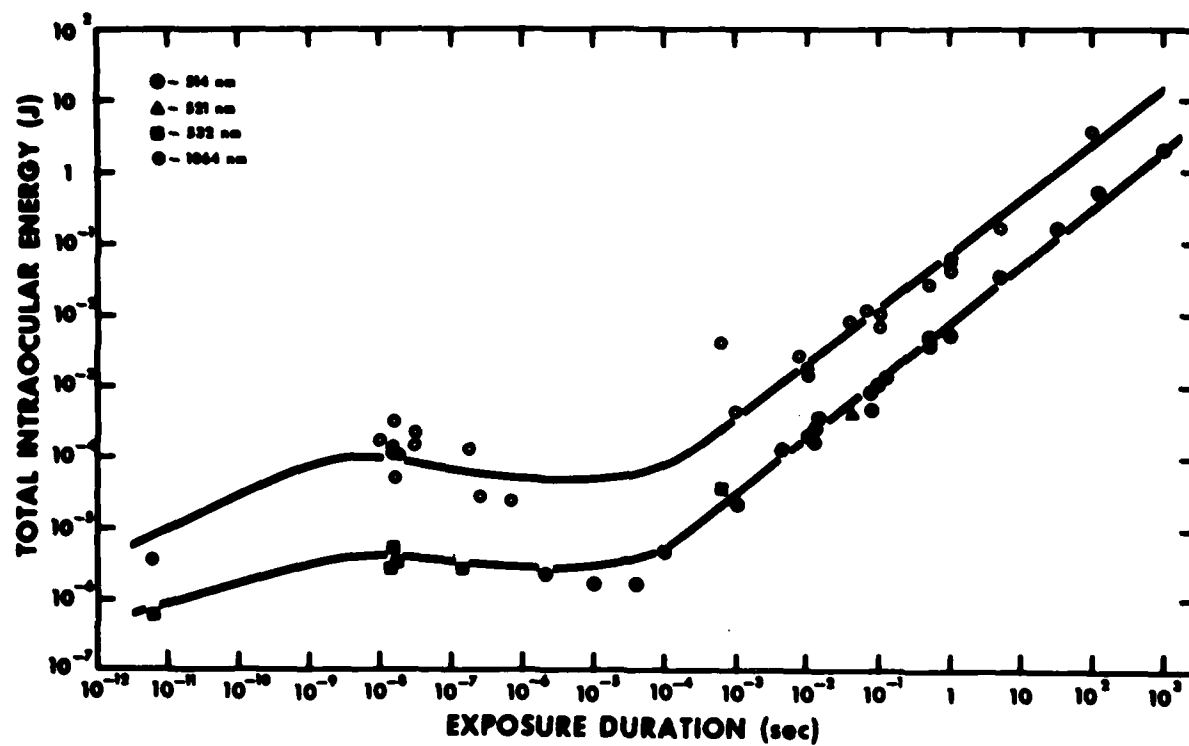


Figure 2 (Stuck). Retinal Injury ED_{50} Thresholds for Minimal Injury of the Retina. Experimental data range from picoseconds to kiloseconds. Upper curve is for 1064 nm, lower curve is for visible (green) light.

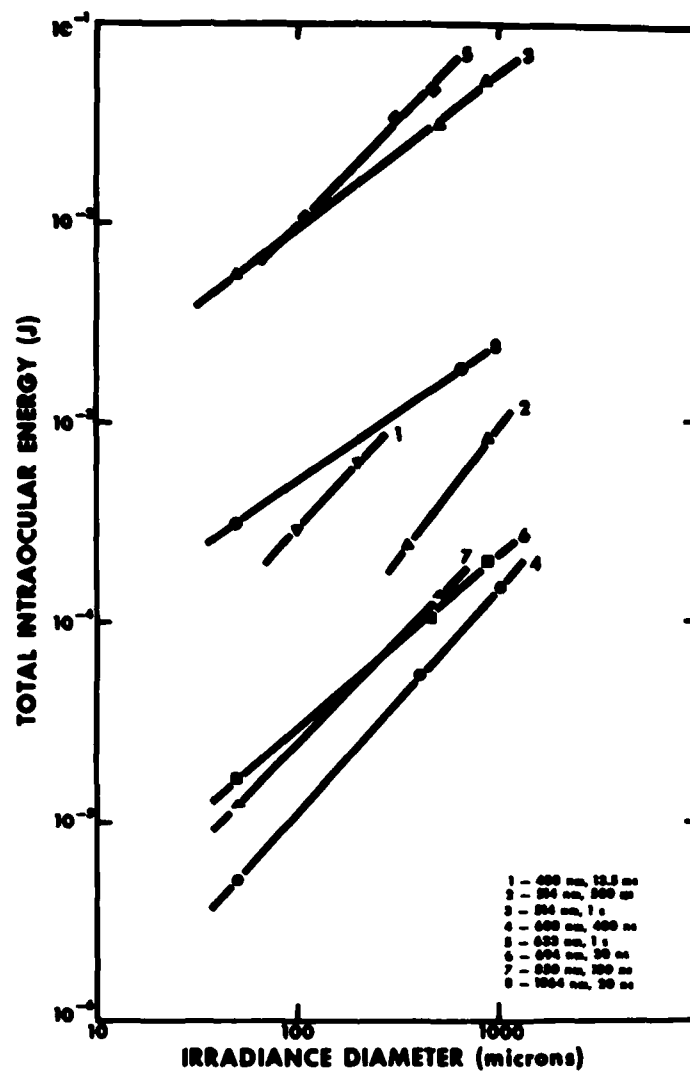


Figure 3 (Stuck). Retinal Injury ED_{50} Thresholds for Large Image Sizes ($50 \mu\text{m}$ to $775 \mu\text{m}$). Note the spot-size dependence regardless of exposure duration from 20 ns to 1 s.

Over the past 4 or 5 years, COL Beatrice and Mr. Jack Lund have been working quite extensively toward defining the effect of repetitive pulse exposures. Here again, an empirical relationship appears to hold over a fairly wide range of PRF's. Specifically, the ED_{50} energy-per-pulse for a given number of pulses into the eye reduces as the number (N) of pulses into the eye is raised to the minus one-quarter power. The plot shown in Figure 4 indicates that this applies for a PRF of 10 Hz and also for a PRF of 100 Hz. One deduces from this curve that for a given time slot there is reduction in the total energy required to produce an ophthalmoscopically visible lesion. The repetitive pulse data shown in Figure 4 were all for a minimal retinal irradiance diameter. Other studies with larger retinal irradiance diameters did not show the same function of N raised to the minus one-quarter power. The most recent study performed by Dr. G. Greiss of Technology Inc. (USAF contract) for 900-micron retinal irradiance diameters showed that the total intraocular energy requirement was very consistent for a number of pulses into the eye, but earlier studies at the Medical College of Virginia showed a drastic drop in energy required as a function of the number of pulses into the eye. So, there are some unresolved issues with respect to the biological data base supporting repetitive pulse exposures.

We have several slides [not reproduced] which show the enormous variations in the "normal" appearance of the monkey's optic disc, macular, and foveal areas. There are no obvious pathological lesions in this eye. Some obvious lesions are shown in Figure 5. However, in light of the emphasis of this meeting, we must remember that, although there may exist no visible pathology, there could be some functional deficit in the performance of that eye. Beginning with higher dose exposures, frank vitreous hemorrhages occur immediately after exposure to a Q-switched pulse (Figure 6). At a lower dose, a retinal hemorrhage with retinal detachment dissecting into the foveal-macular area may occur (Figure 7). Proceeding to lower doses, there is a small lesion.

Figure 8 shows a series of graded lesions placed temporal to the optic disc. At higher doses, the lesions are quite obvious. Proceeding to lower doses, one must examine by 24-hours postexposure to see the four barely visible exposure sites. If you look carefully, they are very small and exhibit a darkened appearance. At other exposure sites, an immediately visible lesion was produced.

Another series of studies, conducted by Dr. Harry Zwick in our laboratory concerns the flash effect of repetitive pulse lasers in a task-oriented, conscious, rhesus monkey. Light exposures are made through the gap in the Landolt ring while the animal is attentive to it. The foveal-macular area of the animal exhibits the characteristic pathology of near-minimal lesions. The doses were near the ED_{50} for the production of retinal burn. These animals did show some deficits in visual acuity measured out to 2 or 3 minutes of arc. Dr. Zwick will discuss his studies later in this symposium.

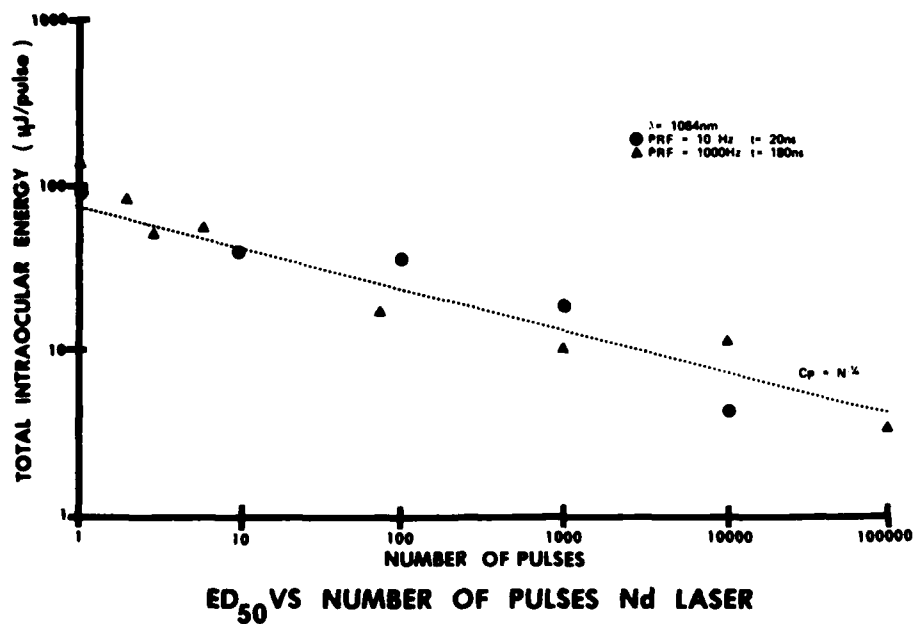


Figure 4 (Stuck). Reduction of ED_{50} Threshold-per-pulse for Increasing Pulse Repetition Rate (PRF)

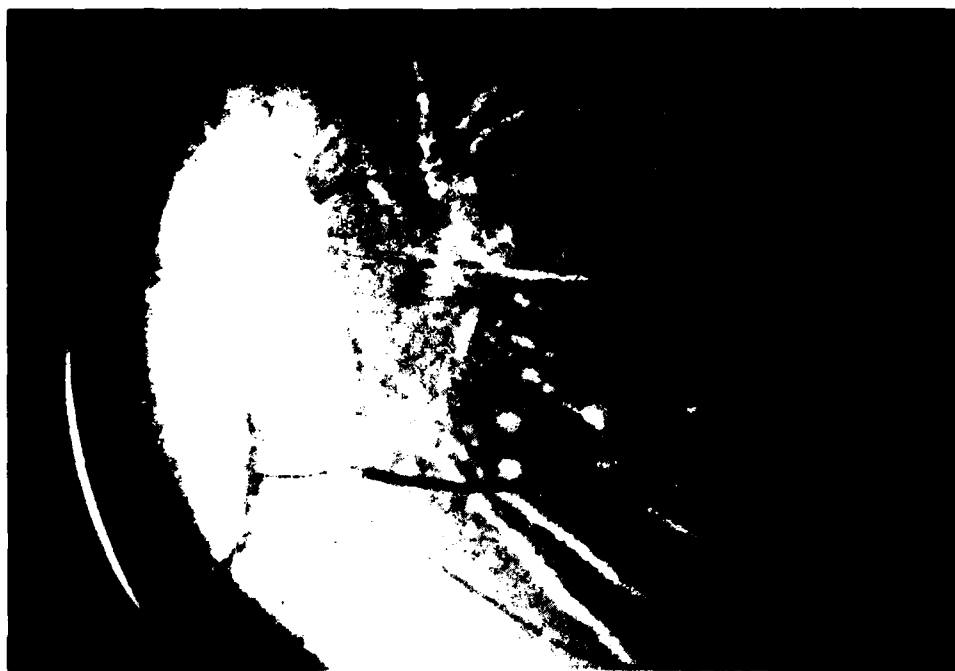


Figure 5 (Stuck). Representative Retinal Lesions in the Rhesus Monkey at Near-threshold

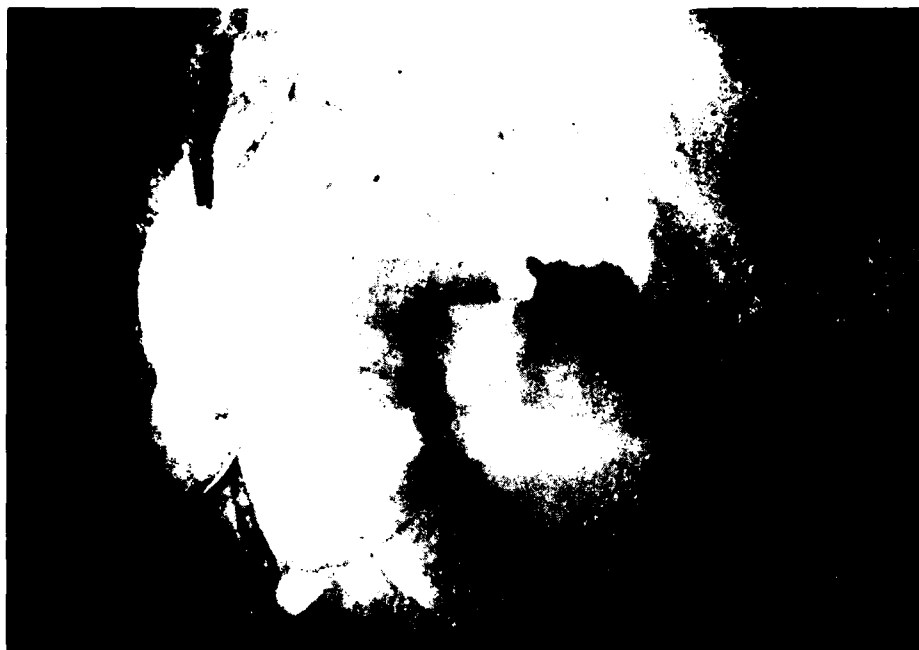


Figure 6 (Stuck). Vitreous Hemorrhage Resulting from Exposure to a Q-switched Laser Pulse

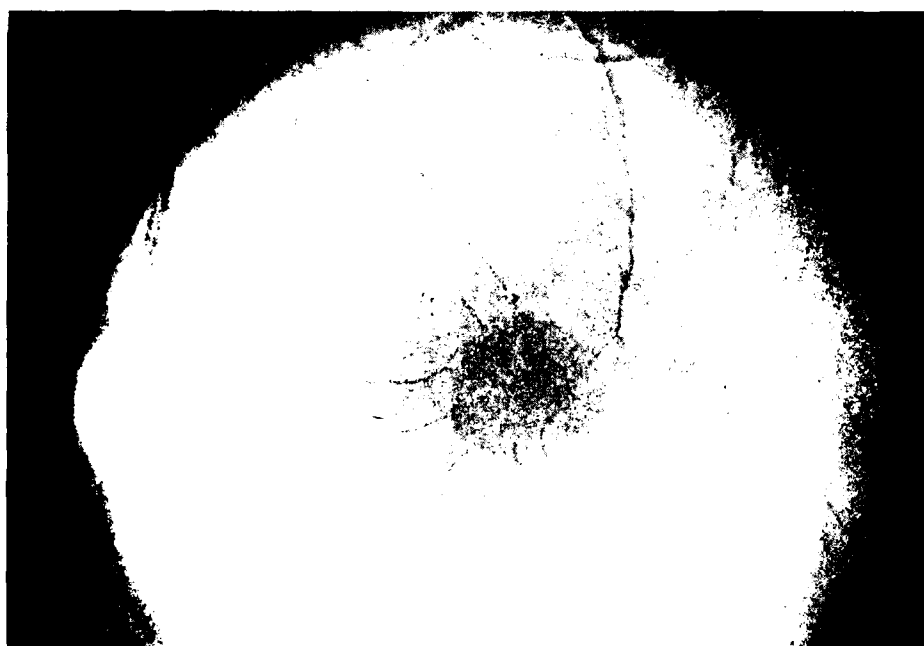


Figure 7 (Stuck). Mild Retinal Hemorrhage in the Rhesus Monkey

Figure 9 indicates some of the tactical ranges at which these different retinal effects might be anticipated for various exposure conditions. As Mr. Slaney indicated, optics increase the hazard, as seen in the increased ranges. A nighttime pupil diameter increases the risk over a daytime pupil diameter. These are at tactically significant ranges and are of concern in training. These laser beam exposure levels are typical of devices that are currently deployed as ruby LRF's and neodymium designators. Our laboratory continues to look at single-pulse effects using the ophthalmoscopic criterion. Primarily, because of the interest in Ga-As lasers, as in the MILES device, there is currently a concentrated effort by Mr. Lund and COL Beatrice to study effects in the 800-900 nm region for single Q-switched pulses. Figure 10 shows the data for a single 532-nm "doubled" neodymium laser exposure, dye laser exposure points, a ruby laser Q-switched pulse exposure, and a point (No. 10) at 1.06 μm . The maximum permissible exposure (MPE) is shown below the ED₅₀ points. The MPE limits have been established for a long time and are supported by this data base and theoretical considerations. But laser bioeffects studies continue to address more specific labeling and exposure conditions, and there may be some surprises still in store for us. Therefore, there is a need to continue some degree of medical surveillance. To what degree I really do not care to comment.



Figure 8 (Stuck). Series of Graded Lesion in a Rhesus Monkey in a 3-by-4 Array

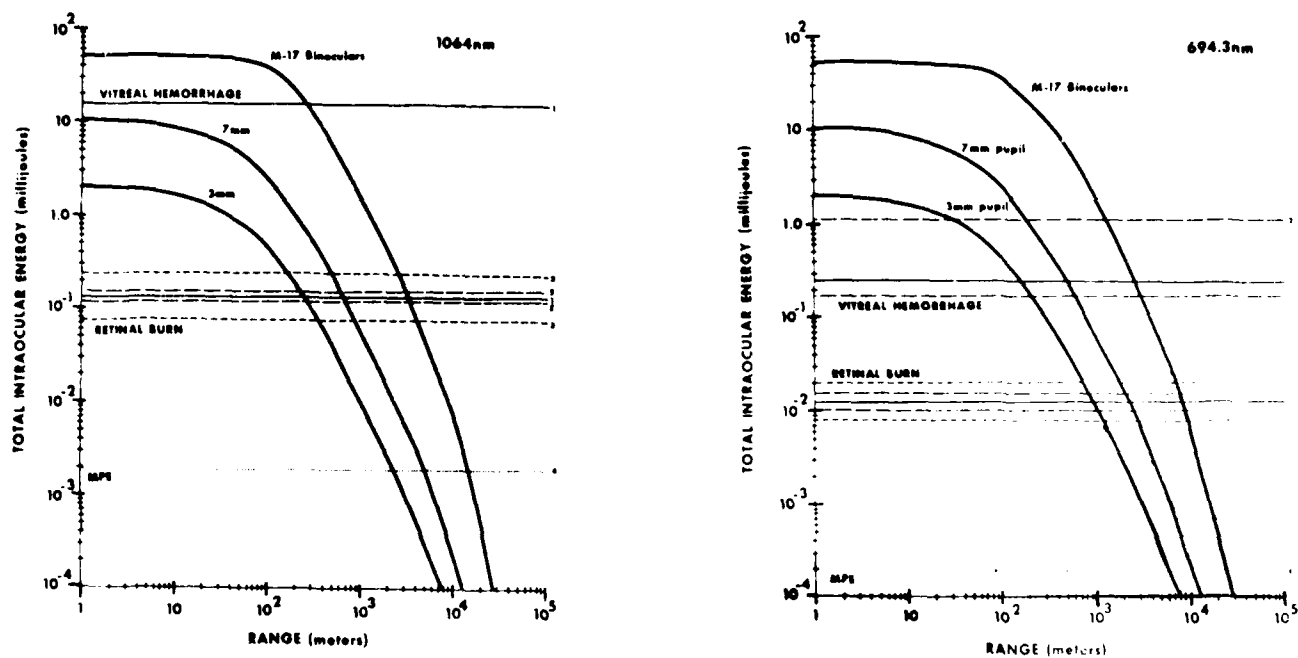


Figure 9 (Stuck). Tactical Ranges Where Laser Effects Can Occur From Military Rangefinders

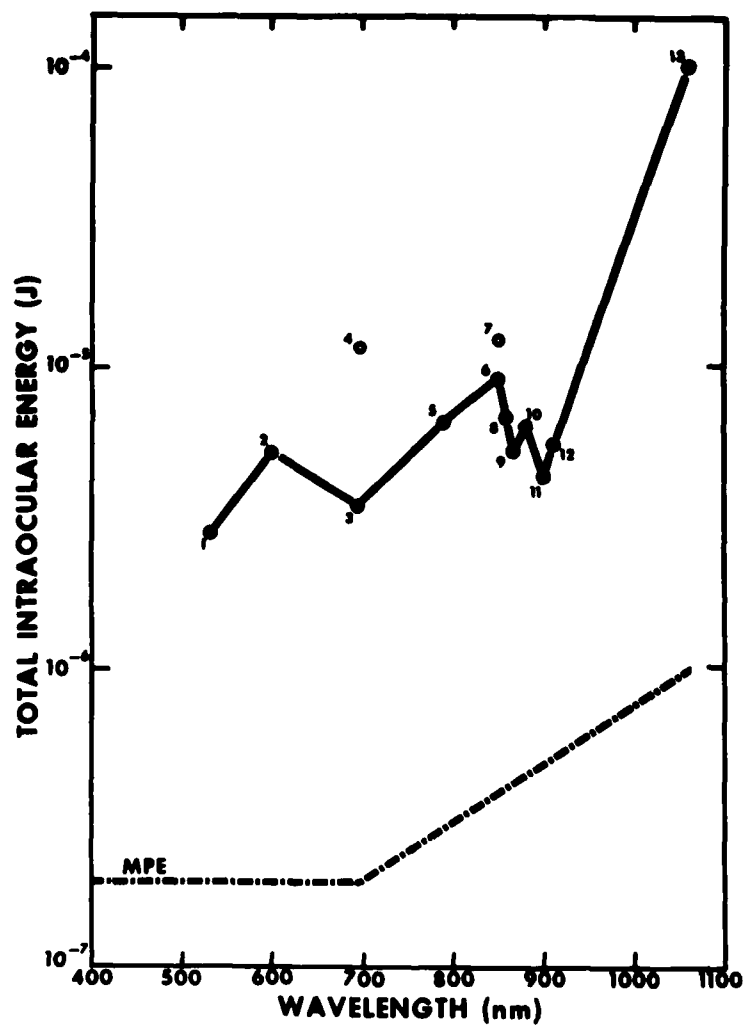


Figure 10 (Stuck). Variation of Experimental Retinal Injury Thresholds in the Rhesus Monkey. The data were obtained by Mr. D. J. Lund of LAIR using a Q-switched Nd:YAG laser to pump a dye laser.

CLINICAL EXPERIENCE WITH LASER ACCIDENTS

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I should like to state at the outset that I am a relative newcomer to the field of laser bioeffects. As a clinical ophthalmologist I have been technically involved with laser photocoagulation for several years, but only in the past 6 or 7 months have I been studying laser bioeffects in COL Beatrice's group.

I will review the medically reported cases of accidental retinal laser injuries appearing in the world medical literature. To date, there have been 18 reported cases. Before reviewing the accident reports, I would like to present a grading scale for foveo-macular retinal laser injuries. The scale is based on ophthalmoscopic findings and relates exposure dose to expected retinal effects. It is based upon rhesus monkey data as well as other available information. This grading scale is really a modification of one appearing in the text of Zweng, Little and Peabody (1969) on laser photocoagulation. The Zweng scale is based on a ruby laser lesion in the rhesus monkey and is graded as 1 through 5 based upon ophthalmoscopic findings.

Grade 1 lesions are seen as white spots in the retina and represent either retinal edema or retinal coagulation. Grade 2 lesions are white spots with the additional presence of an intraretinal vapor bubble. These are seen as highly refractile tiny spots in the center of the lesion which generally disappear within a few minutes. Grade 3 lesions are characterized by the presence of white spots, from which the vapor bubble has escaped into the vitreous. This usually indicates a break in the internal limiting membrane of the retina. Grade 4 lesions are associated with intraretinal blood in addition to the white retinal lesion. In Grade 5 lesions, the hemorrhage has broken into the vitreous. These authors regarded this grading scale as a guide for laser photocoagulation treatment, and they recommended aiming for a Grade 1 or Grade 2 lesion. That is to say, lesions with just retinal edema, or possibly with a vapor bubble as well, are the most desirable for laser photocoagulation.

To this grading scale for foveo-macular retinal laser injuries, I will present a few necessary modifications for application in evaluating accidental laser injuries. For example, vapor bubble formation is very unlikely to be seen in accident victims due to the usual time delay before examination. In this grading scale, we have foveo-macular retinal laser injuries graded on ophthalmoscopic findings. I shall relate the reported lesions to exposure dosages which could be expected to cause the reported lesions. The lesions are graded 1 through 4 and subdivided into groups A and B, depending on location: either foveal or extrafoveal. For the purpose of this grading scale, we consider the avascular zone as being within the fovea. The relative exposure doses are multiples of the

ED₅₀. The ED₅₀ is defined as the ophthalmoscopic detection of a minimal retinal alteration that is visible within 1 hour after the exposure. Of course, the ED₅₀ levels are dependent upon the wavelength, the retinal spot size, pulse duration and PRF, as well as other factors. These relative doses are for foveal lesions and, from clinical experience and laboratory studies (e.g., Gibbons and Allen, 1978; Ham and coworkers, 1970; Marshall, 1970; Wolbarsht and Landers, 1979) more energy is required to produce lesions outside of the fovea than within the avascular zone. Grade 1 lesions are characterized ophthalmoscopically by the presence of retinal edema only. Grade 1 lesions can be expected to be caused by exposures approximately twice the ED₅₀.

Retinal necrosis characterizes Grade 2 lesions. Technically, retinal necrosis is a histopathologic diagnosis; however, an ophthalmoscopic distinction between retinal edema and retinal necrosis is based on the intensity of the white lesions. The retinal edema is characterized by a relatively light white color through which the choroidal background color often can be seen, whereas a retinal necrotic lesion would be a very heavy white burn often associated with a thinning of the retina in the area. Grade 2 lesions would be expected to be produced by exposures five times the ED₅₀.

Grade 3 lesions are characterized by the presence of either a subretinal hemorrhage or fluid and hemorrhage within the confines of the retina. This can be expected to be produced by exposures 10 times the ED₅₀.

The most serious are Grade 4 lesions. These are characterized by the presence of a hemorrhage which has dissected through the retina into the preretinal or subhyaloid space or into the vitreous cavity. It may or may not be associated with a full-thickness retinal hole. This type of injury can be expected to be produced by an exposure 50 times the ED₅₀.

With this grading scale, we can now discuss the accident reports. Rathkey was the first to publish a case report of a retinal laser accident (Rathkey 1965). The accident occurred in February 1964. A college student accidentally viewed a pulsed ruby laser (694.3 nm) with his right eye. The laser had a pulse duration of 0.8 ms with an unknown energy output. He was examined within 20 minutes of the accident. This period is the shortest of any reported. At that time, his best corrected visual acuity was 10/200. Under ophthalmoscopic examination, he had macular edema and a dense central scotoma. Over the next few weeks, a pigmented macular scar developed, and at 6 weeks his visual acuity was 20/200. An eye examination prior to the laser accident had revealed 20/20 vision in the injured eye. By our grading criteria this would be characterized as a Grade 1 lesion.

The second case was reported a little bit later the same year, 1965, in the French ophthalmic literature (Blancard, 1965). The accident occurred in October 1964. An electrician was accidentally exposed to a pulsed ruby laser due to a faulty shutter. The pulse duration was 100 ns; the energy was estimated at less than 100 millijoules (mJ). An immediate positive

scotoma and reduced central vision were noticed by this electrician. When he was examined, a 6-degree positive central scotoma was present and there was foveal edema, retinal hemorrhage, and vitreal hemorrhage. Two months after the incident, a persistent central scotoma remained along with a pigmented macular scar.

The next two cases were reported by Jacobson and McLean in a letter to the Editor of the Archives of Ophthalmology (1965). They described two laser workers who were found to have small, white, discrete, retinal burns. One of the workers reported that he had viewed a laser beam reflected from a piece of glass. He had a visual field defect corresponding in size and location to one of the retinal lesions. However, this is a rather short report. The type of laser and the energy levels were not mentioned; presumably these lesions were Grade 1 or Grade 2 at most.

In 1968, Curtin and Boyden (1968) reported a case from Bethesda Naval Medical Center. A 21-year old white male naval midshipman was working in a laser laboratory in October 1965. He accidentally viewed a pulsed ruby laser reflection from a piece of blue chalk with his right eye. He instantly felt a windlike force against his face and saw a bright orange light. He experienced immediate blurring of vision in his right eye. He was examined the same day and found to have a best corrected visual acuity of 20/100, a 3-degree absolute central scotoma with macular edema, and foveal hemorrhage. He was treated with topical corticosteroids and mydriatics and, in the next 2 weeks, developed a macular hole. The visual acuity remained 20/100, and the absolute central scotoma was still present 12 months following the accident. CAPT Blaise tells me that he can provide a 20-year followup on this case.

COMMENT: CAPT Blaise: This case is currently up for evaluation by the Disability Board and he presently has a macular hole, slight elevation of the retina surrounding the macular hole, posterior vitreous detachment, and visual acuity of 20/400 in that eye with a slight amount of neovascularization within the area of the hole. Fluorescein angiography for the past 10 years shows essentially no changes in the retina although the patient reports that he has significant symptoms of photopsia, etc. None of these symptoms can be collaborated by the ophthalmologists who have performed the evaluations. At the present time, the patient has a slight detachment of the retina, but the remainder of the retina is intact and attached. I believe he now has an approximately 10-degree central scotoma. The patient maintains that where the vitreous has detached there exists a scintillating scotoma, etc. We have difficulty interpreting this since he is trying to obtain a medical discharge from active duty, whereas the clinical findings remain unchanged from those reported by Curtin and Boyden.

QUESTION: Dr. Zwick: Does he have normal color vision?

QUESTION: COL Whitmore: Is there actually a full thickness hole or is there just a partial hole with undermining....?

COMMENT: COL Tredici: I think the most curious part of this report is that the laser energy must have been enormous since he viewed a ruby laser reflection off blue chalk. This means that half of the energy was absorbed by the chalk. Perhaps these details may have been glossed over, as it was a medical report. It would be very interesting to find out what he was actually doing.

COMMENT: Dr. Wolbarsht: There is no way he could have received that injury without looking into the beam on purpose. He must have fabricated the report.

COMMENT: COL Tredici: That is what I mean, the blue chalk reflection would seem to be much too weak.

CAPT Wolfe (continues): The next reported accident case was from Chris Zweng (1967) in the Archives of Ophthalmology. In March 1966, a scientist in a physics laboratory received an accidental exposure to his right macula from a Raman shifted Q-switched ruby laser beam reflected off a glass bottle. The laser was emitting wavelengths of 650, 694.3, and 746 nm. By reconstructing the accident, it was calculated that an energy of 103 mJ had entered the eye. The scientist noted almost immediately a paracentral scotoma. The initial examination occurred within 19 hours following the exposure. At that time, he was found to have a best corrected visual acuity of 20/25 -2 and a macular lesion that seemed to involve the fovea. Amsler grid central visual field showed distortion temporal to fixation in that eye. He was treated with 80 units of corticotropin intramuscularly and his vision improved from 20/25 -2 to 20/15 -2, 27 days following the exposure. He developed a scar just nasal to the fovea. At 8 months following the injury, he had a paracentral scotoma of 23 minutes.

The next case was described by Henkes and Zuidema (1975) in the European literature. In this report, a 21-year-old laboratory worker was working in a sparsely lit room and was accidentally exposed in the right eye to a Q-switched, frequency-shifted ruby laser beam. In reconstructing the accident, it was determined that the wavelength of the incident beam was 800 nm and that the corneal radiant exposure was 3 mJ/cm². The total energy entering the eye was calculated to be 0.377 mJ, assuming a 4 mm pupil. The pulse duration was 20 ns and the pulse interval was 3 seconds (or 20 pulses per minute). The worker immediately saw a rapidly expanding black spot, surrounded by a ring of colored lights. He was examined the following day and found to have a visual acuity of 20/200 and a 5-degree central scotoma. He had an intraretinal hemorrhage in the fovea which had broken through into the vitreous. He was tested with the American Optical-Hardy, Rand, and Rittler (HRR) pseudoisochromatic plates and the Farnsworth D15 color panel; these tests were normal. However, in an anomaloscopic examination, more red was required. A foveal ERG was performed and found to be markedly reduced in the involved eye. There was a less pronounced difference between the two eyes of the VEP. He was given a retrobulbar injection of 40 mg of triancynalin and also several intravenous infusions of high-molecular-weight dextran. These were given

over the course of a couple of weeks in order to promote the resorption of the vitreal hemorrhage. The vision gradually improved to 20/50 and was stable at 3 months. The central scotoma had reduced in size and persisted. There was a through and through retinal hole. This was a Grade 4 lesion since there was both an intravitreal hemorrhage and a retinal hole formation.

The next seven cases were reported by Boldrey, et al. (1981). Their first case occurred in June 1979, when a 31-year-old white male laboratory worker accidentally exposed his left eye to a Nd:YAG laser (wavelength: 1064 nm, 10 pulses/second and a pulse duration of less than 1/10 of a second). The beam diameter was 500 microns and the energy delivered was 15 mJ per pulse. The man immediately heard a snapping sound and saw a bright afterimage for 20 minutes, which faded to a dense central scotoma. When he was examined later that same day his visual acuity was 20/300 with an absolute central scotoma, a blood clot over the fovea, two preretinal hemorrhages, and a vitreous hemorrhage. Figure 1 is a retinal photograph on the day of the injury. There is dense foveal edema and diffuse edema of the macula. After 9 days, a full-thickness, 500 μ m retinal hole could be seen. Figure 2 is the macula 3 months later. One can see a large, full-thickness hole in the center of the fovea.

Their second case occurred in January 1977, when a 32-year-old white male laboratory worker who accidentally exposed his left eye to a Q-switched Nd:YAG laser (wavelength of 1064 nm, 10 pulses per second, and a pulse duration of 6 ns). The beam diameter was estimated to be 1.5 to 3 mm, and the energy delivered was 6 mJ per pulse. The worker felt an immediate pop and a sudden pain accompanied by blurred vision, floaters, and photopsias. When he was examined the next day the visual acuity was 20/20, but there was an inferior Bjerrum's scotoma. Fundus examination showed a 2/3-disc diameter area of retinal edema just superior-temporal to the disc with a small central retinal hole (Figure 3). There was a retinal blood clot connected to a diffuse vitreous hemorrhage. Most of the vitreous had cleared by 2 weeks, and by 3 months a nerve fiber layer defect could be seen. Figure 4 is the lesion 3 months after the injury. This case would also be a Grade 4 lesion since there was a vitreous hemorrhage and retinal hole formation.

The third case reported by Boldrey (1981) occurred in December 1979, when a 27-year-old graduate student accidentally exposed his left eye to a pulsed Nd:YAG laser (wavelength 1064 nm, pulse duration 20 ns, and probably pulsed at 10/s). The beam diameter was 2 1/2 mm, and the energy output was 1 to 2 mJ per pulse. At the time of the accident, he saw a peripheral flash which he looked at instinctively. He had an immediate decrease in visual acuity and an immediate central scotoma. When he was examined 1 day later, the best corrected visual acuity was 20/100, with a central scotoma. There was a 3/4-disc diameter subretinal hemorrhage under the fovea. His vision improved gradually to 20/50 by 5 days, 20/25 by 6 weeks, and by 4 months his visual acuity was 20/20 -3 and pigmented scar had formed. The central scotoma was reduced in size and only noticeable during Amsler grid testing. Figure 5 is the lesion 1 day after the injury, showing the large subretinal hemorrhage, and Figure 6 shows the retina 4 months later with a pigmented scar on the fovea.

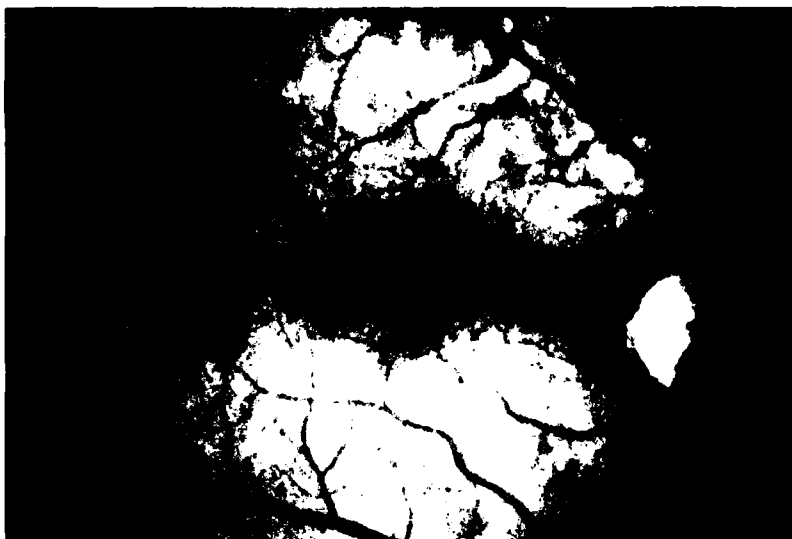


Figure 1 (Wolfe). Boldrey, et al. (1981) - Case 1 - Appearance on the Day of Injury

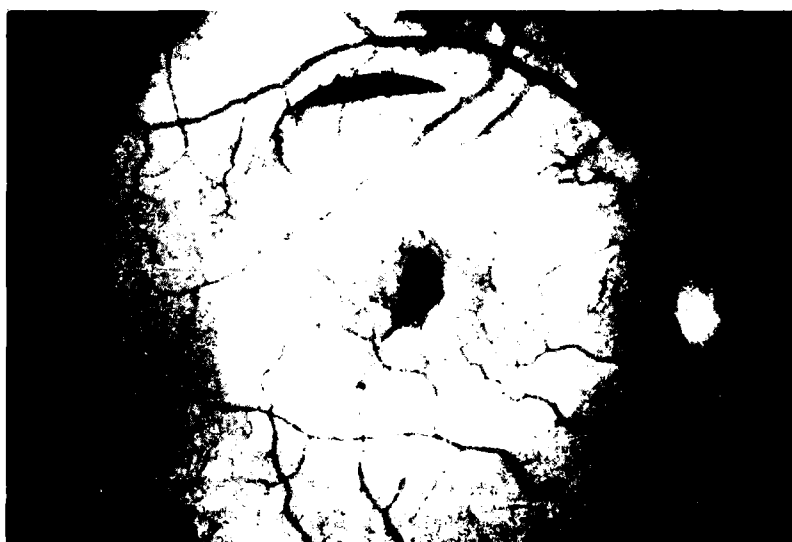


Figure 2 (Wolfe). Boldrey, et al. (1981) - Case 1 - Appearance 3 Months Following Injury

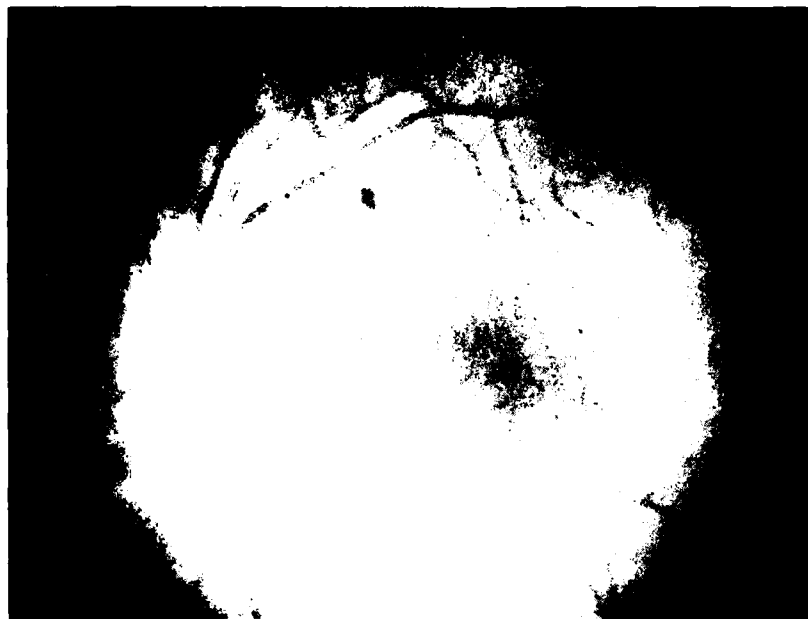


Figure 3 (Wolfe). Boldrey, et al. (1981) - Case 2 - Appearance on the Day After Injury



Figure 4 (Wolfe). Boldrey, et al. (1981) - Case 2 - Appearance 3 Months After Injury



Figure 5 (Wolfe). Boldrey, et al. (1981) - Case 3 - Appearance 1 Day After Injury



Figure 6 (Wolfe). Boldrey, et al. (1981) - Case 3 - Appearance 4 Months After Injury

The fourth case reported by Boldrey, et al. (1981) occurred in April 1971, when a 31-year-old white male laboratory worker accidentally exposed his left eye to a continuous wave (CW) argon laser (wavelengths: 488 nm and 514.5 nm). The beam diameter was 1.44 mm, and the exposure time was estimated to be 0.125 second based on the blink reflex. The energy incident on the cornea would have been 8 to 9 mJ. He noticed an immediate paracentral visual blur. He was examined the next day and the visual acuity was 20/20; however, the visual acuity in the fellow eye was 20/15. In the injured eye there was a 1-degree paracentral scotoma. Fundus examination revealed a 50-100 μ m area of dense retinal necrosis superior nasal to the fovea. By 12 days, the visual acuity was 20/15 -2 and the edema had cleared leaving a juxtafoveal depression in the retina. By 2 months, no visual field defects remained although a tiny pigmented scar persisted.

The fifth case reported by Boldrey, et al. (1981) occurred in April 1978, when a 24-year-old white male laboratory worker accidentally exposed his right eye to a CW argon laser (wavelengths: 488 and 514.5 nm). The exposure occurred from reflection off a Brewster window. The beam power was estimated to be less than or equal to 25 mW. The beam diameter probably was less than 1 mm. Based on a blink reflex of 125 ms, an estimated 3-4 mJ would have been incident on the cornea. At the time of the accident, the worker saw a flash of light at which he instinctively looked. He then had an immediate visual blur and scotoma. He was examined 3 days later, with a visual acuity of 20/20 -2. His fellow eye was 20/15 at this time. He had a small central blur on the Amsler grid. There was a tiny area of retinal necrosis at the edge of the fovea with surrounding subretinal hemorrhage, fluid, and edema. By 1 week after the injury, the visual acuity had fallen from 20/20 -2 to 20/25 and he was treated with 60 mg of oral prednisone daily for 5 days. By day 11 following the injury, the visual acuity had improved to 20/15 and the retinal edema had cleared. In Figure 7 (bottom), one can see the appearance at 3 days after the injury (bottom right) and 2 weeks later with the clearing of the edema (bottom left).

The sixth case reported by Boldrey (Figure 8, top) occurred in August 1979, when a 34-year-old white male laboratory worker accidentally exposed his left eye to a pulsed Rhodamine 6-G dye laser (wavelength: 592 nm to 594 nm, beam diameter of 6 mm, pulse duration of 10 ns, and PRF of 10 Hz). The maximum energy incident on the cornea was estimated to be 0.2 mJ per pulse. The worker saw an orange flash followed by an immediate visual blur and scotoma. When he was examined 1 day later, his visual acuity was 20/25, with a small central scotoma. There was a pale area of retinal necrosis 50-100 μ m in diameter at the nasal edge of the fovea. The top two photographs of Figure 8 are from this case. The one on the left is the retina as it appeared 1-day after the injury, and the one on the right is 2 weeks later. By 8 days, the retinal edema was clearing, his visual acuity was 20/20, and the visual field defect was smaller. By 2 weeks, all edema had cleared, a pigmented scar had formed, and the visual field defect remained stable. By 3 1/2 months, the field defect was only noticeable to the patient during testing for it. It is interesting that this patient,

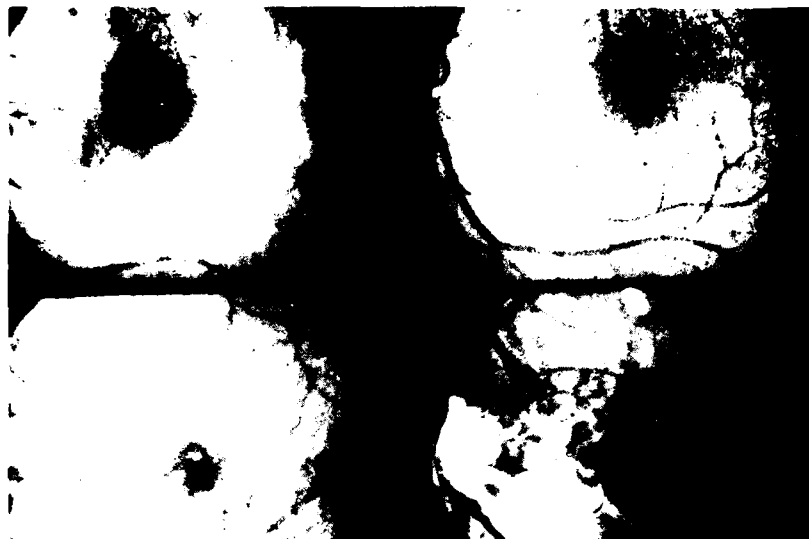


Figure 7 (Wolfe). Boldrey, et al. (1981) - Appearance of Injury. Case 4, Top; Case 5, Bottom



Figure 8 (Wolfe). Boldrey, et al. (1981) - Appearance of Injury. Case 6, Top; Case 7, Bottom

when initially examined after this accident, had pathology in the right (supposedly uninjured) eye: retinal pigment atrophy and clumping approximately 100 μm in diameter at the temporal edge of the fovea. At that time, in the right eye, the best corrected vision was 20/25. Previous examinations showed 20/20+ vision in each eye and normal visual fields. Unfortunately a fundus examination was not reported in the previous examinations, but we do know that his visual acuity dropped and he now had a similar lesion in the other eye that must have occurred asymptotically.

The seventh case reported by Boldrey occurred in February 1979, when a 35-year-old white male laboratory worker accidentally exposed his right eye to a CW krypton laser beam reflected from a bubble. The wavelength of the laser was 647.1 nm to 674.2 nm. The energy and fraction of the beam reflected to the man's eye were unknown. He noticed an immediate visual blur and scotoma. One day later, his visual acuity was 20/20 tangentially, with a 1 degree paracentral scotoma. There was a round area of retinal necrosis about 50 μm in diameter at the nasal edge of the fovea. By 8 days, the retinal edema had cleared and there was a tiny area of depigmentation which remained along with the field defect during a 16-month followup period. Figure 8 shows the acute picture 1-day after the injury (left) and the following several months later (right).

The last four accident reports are from the Russian ophthalmic literature and were reviewed by Balashevich and his coworkers (1981). They reported four cases--unfortunately with no photographs.

The first case occurred in a female graduate student who accidentally exposed her right eye to a Q-switched ruby laser beam reflected from a crystal. The wavelength of the laser was 693 nm; the pulse duration was 80 ns. The energy levels were not recorded. At the moment of injury she saw a bright red flash followed by a dark spot in the center of her visual field. Examined 8 hours after the injury, she showed retinal edema in the fovea and a foveal intraretinal hemorrhage. The visual acuity was 20/100. Initially she had a 4-degree absolute paracentral scotoma. She received osmotherapy and vitamin and tissue therapy, along with a series of injections, which I presume represent some type of fever treatment analogous to giving her steroids. I suppose this would be to stimulate her adrenals. Three weeks afterwards, her vision had improved to 20/50, and by 2 months it was 20/25. By virtue of the intraretinal hemorrhage, this would have to be considered a Grade 3 lesion.

Balashevich's second case occurred to a scientific assistant who injured a left eye from direct exposure to ruby laser radiation while he was sighting through the output aperture with the device shut off. At that time, the capacitor discharged unexpectedly. The wavelength of the laser was 693 nm and the pulse duration was reported to be 300 ms. No energy level was reported. A sharp flash was perceived by this scientist followed by complete loss of vision for 1 or 2 minutes. Peripheral vision returned, but a central dark spot remained. He was examined 24 hours later and had a macular hemorrhage with best corrected visual acuity of 20/100 with a 2- to

3-degree absolute central scotoma. He also received corticosteroids, osmotherapy and stimulation therapy. Ten days after the injury his vision had returned to 20/20. A pigmented lesion was apparently present in the area of a macula hemorrhage at that time. This also would be a Grade 3 lesion.

Balashevich's third case was an engineer who injured his right eye while he was adjusting a Q-switched Nd:YAG laser (wavelength of 1060 nm with a pulse duration of 50 ns). He was struck by a beam that was reflected by a mirror. He perceived a very sharp flash followed by a very dark spot in front of his eye running upward from fixation. Again, the energy exposure level was not reported in the translation, although it may have been in the original article. In Balashevich's summary, he alluded to energy levels as if they were reported in the original article. This patient was examined 48 hours after the injury and showed a macular hemorrhage, a macular hole formation, and a vitreous hemorrhage. His vision was 20/100, and he had a 3-degree absolute central scotoma. He received corticosteroid, osmotherapy, and stimulation therapy. Sixteen days after the injury, his visual acuity had improved to about 20/70, and he now had a 1-degree absolute central scotoma. The visual function was about the same at 6 months after this injury without any further improvement.

The last case of Balashevich's was a scientific assistant who received an injury in the right eye from a reflected beam off a glass component. The laser was a pulsed Nd:YAG laser (wavelength of 1064 nm with a pulse duration of 30 ns). He wasn't examined until 8 days after the injury when he was found to have a subretinal and preretinal hemorrhage. His visual acuity was between 20/50 and 20/70, and he had a relative central, as well as absolute paracentral, scotoma of 8-10 degrees and 4-5 degrees, respectively. He received corticosteroids, osmotherapy and stimulation therapy. Fifteen days after the injury, his visual acuity had improved to between 20/24 and 20/50, with reduction in the size of the relative central scotoma and reabsorption of the subretinal and preretinal hemorrhage.

These 18 cases represent all of the medically reported retinal laser accidents. Unfortunately, they leave many gaps in the information that is needed to prevent human laser injuries. Often the energy output of the laser source is not documented. Even when the total energy into the eye is reported, it is really based on a reconstruction of the events and, thus, is only a guess. Nevertheless, I think these cases do provide some useful information. Most of these exposures appear to be suprathreshold, and the effects produced seem to corroborate the data available from suprathreshold exposures in nonhuman primates. Furthermore, from the military perspective, these accident victims constitute a fairly representative group. The majority of them were sound, in their early twenties to midthirties. Most of them were males who had had healthy eyes until the time of the injury. This is unlike most of the data we have from human medical laser exposures. Where stated, the victims were white. More heavily pigmented individuals would, of course, be expected to be at an even greater risk to injury from exposure. There are two additional cases of possible laser accidents that deserve to be examined. But before leaving these documented accident cases, a look at the visual effects produced with respect to the grade of injury is warranted.

The following Table lists injuries, Grades 1A through 4A, along with the visual effects that are produced by lesions of each grade according to the data available from the accident reports. It should be pointed out that the visual effects reported here are clinically measurable effects and do not really include more subtle, nonclinically measurable effects such as changes in spectral sensitivity and low-level contrast sensitivity which have been shown to occur after laser exposure. One also sees with Grade 1A lesions an associated range of visual acuity from 20/15 to 20/25 along with a paracentral blur to paracentral relative scotoma. With Grade 2A lesions, the visual acuity seems to range between 20/15 to 20/40, and there is also the presence of a paracentral (relative to absolute) scotoma. With Grade 3A lesions, the visual acuity ranges from 20/15 to 20/50, also with the relative to absolute paracentral scotoma, and with or without the presence of photopsias. With Grade 4A lesions the visual acuity ranged from 20/15 to potentially counting fingers or worse. The most severe consequences did not occur in any of these accident cases. When a relative to absolute paracentral scotoma is present, there may or may not be photopsias and/or floaters. It should be noted that some of these accident victims had a visual acuity of 20/20 when they were first seen; however, that was abnormal for them. They often had an associated paracentral scotoma or defect in their Amsler grid. Their fellow eye often had a better visual acuity. When the lesion resolved, the visual acuity in the injured eye often improved to better than 20/20.

TABLE (Wolfe). RANGE OF VISUAL ACUITY IN EARLY PHASE AFTER INJURY

Grade	Ophthalmoscopic Findings	Subgrade A	Subgrade B
I	Retinal edema	20/15 to 20/25	20/30 to 20/200
II	Retinal necrosis	20/15 to 20/40	20/40 to 20/400
III	Subretinal and/or intraretinal hemorrhage	20/15 to 20/50	20/100 to 20/400
IV	Vitreous hemorrhage and/or full-thickness retinal hole	20/15 to Fc or worse	20/100 to Fc or worse

A = extrafoveal lesion; B = foveal lesion; Fc = finger counting

In the Table, Grades 1B to 4B lesions are listed, along with the visual effects seen in the cases. In Grade 1B lesions the visual acuity ranged from 20/30 to 20/200, along with a relative to absolute central scotoma. Grade 2B lesions produced a visual acuity ranging from 20/40 to 20/400, also with a relative to absolute central scotoma. In Grade 3B lesions, the visual acuity ranged from 20/100 to 20/400. There was a relative to absolute central scotoma, with or without the presence of photopsias. The Grade 4B lesion (the worst of all) leads to a visual acuity ranging from

20/100 to potentially counting fingers or worse, along with a relative to absolute central scotoma photopsias and/or floaters. With respect to this level of injury, the Grade 4B injuries with vitreous hemorrhage can be expected to lead to a more or less profound effect on the visual acuity, depending on the location of the source of the bleeding with respect to the macula. Superior and superior-temporal bleeding sites can be expected to have a pronounced effect on visual acuity in probably greater than 50 percent of the cases whereas a nasal source of hemorrhage probably would seriously reduce visual acuity in about 25 to 30 percent of the cases. An inferiorly located bleeding site would be much less likely to affect visual acuity, perhaps only in about 10 percent of the cases. Furthermore, massive vitreous hemorrhage--enough to fill the vitreous cavity with blood--would obviously have an extreme effect on visual acuity, reducing it to hand movements or light perception. The capacity of an exposure to produce massive vitreous hemorrhage would be related to the location of the lesion with respect to the underlying choroidal vasculature. For example, a lesion that happened to strike over one of the large vortex vein ampull would much more likely result in massive vitreous hemorrhage than an exposure occurring where large choroidal vessels were absent underneath. The energy that would be required to produce a massive vitreous hemorrhage probably would be of the order of tenfold, the ED₅₀ for vitreous hemorrhage. The ED₅₀ for vitreous hemorrhage was 50 times the ED₅₀ for minimal retinal alterations, thus requiring about 500 times that level for massive vitreous hemorrhage.

Now I shall address the two additional cases. They are interesting and deserve this groups' attention. These two cases were presented by Dr. Richard Finney of LAIR at the annual ophthalmology meeting held at the Walter Reed Army Medical Center earlier this year. Since 1975, the military has conducted laser field tests at Fort Hunter Liggett, California. Throughout the summer of 1981, a large number of personnel were involved in the field testing of the Target Acquisition and Designation System (TADS) mounted on the Advanced Attack Helicopter (AAH). Before and after the field exercise fundusoscopic screening test was required of all personnel involved in this field exercise. The screening consisted of direct fundusoscopic examinations through dilated pupils by optometrists from the Silas B. Hays US Army Community Hospital at Fort Ord. Any abnormalities that were noted on either the prescreening or the postscreening were referred to the ophthalmologists at Silas B Hayes. The following cases probably represent two of the most dramatic referrals.

The first case was a 35-year-old electrical technician who had worked for the Department of Defense at Fort Hunter Liggett since 1974. He worked predominantly in a trailer that was near the laser ranges where telemetry data were recorded from the targets of the LD's. He reported to the Eye Clinic at Silas B. Hayes in October 1981 before these field exercises began. He was asymptomatic, both when he was seen by the screening optometrist and when he came on referral to Silas B. Hayes in October 1981. He stated that, other than being a low myope, he had no visual complaints and he couldn't recall any prolonged exposures or blurred

vision, but he did relate one laser episode that occurred about 1 year earlier. He compared that episode to what happens when one is exposed to a flash bulb. He had a scotoma which lasted for a few minutes and wasn't associated with any sequelae; however, he couldn't recall the circumstances surrounding that episode. An examination performed by an ophthalmologist in April 1978 showed no abnormalities of the fundus. When he was first seen in the Eye Clinic, his pupils were predilated, and pinhole visual acuity was 20/30 in the right eye and 20/40 in the left eye. However, I think this lower visual acuity was a result of his dilated pupils. I believe his vision was actually normal. His Amsler grid and slit-lamp examinations were normal at that time. Indirect ophthalmoscopy of the right eye revealed about 12 creamy yellow, slightly irregular spots which varied from 75 to 100 μ m in diameter. These were located in a linear pattern in the temporal macula. There was minimal pigmentary hyperplasia surrounding a few of these lesions, which appeared to be at the level of the outer retina and choroid. The right fundus showed an extension of these lesions temporal to the macula (pseudovitelliform). The fundus of the left eye showed about 20 lesions of a similar size, shape, and level, but in a more clustered pattern in the temporal macula. The retinal periphery in this patient was otherwise normal bilaterally. Fluorescein angiography showed transmission hyperfluorescence in the areas corresponding to these lesions. He was seen 1 month later and found to have a visual acuity of 20/20 in each eye and essentially unchanged.

The second case was a 25-year-old white male Army sergeant who reported to the Eye Clinic at Silas B. Hayes in October 1981, stating that, for the past 5 weeks, he had noted markedly reduced vision in his left eye. He noticed this when he momentarily occluded the right eye. He did not notice any change in his visual acuity during this 5-week period. He did state that a few weeks preceding this onset of reduced vision, he was involved in an episode at Fort Hunter Liggett that he related to his decrease in vision. He stated that, 2 or 3 weeks prior to the onset of reduced vision, he had been a tank commander on one occasion on the opposing force that was being attacked by the AAH. During the field exercise, he contended that, on two occasions, the left lens fell out of his laser protective spectacles. At that time, he did not notice any visual symptoms. When he was seen for the pretest screening examination in May 1981, his visual acuity was 20/20 in each eye, and his fundus was normal. However, when he reported to the Eye Clinic in October 1981 he had a best corrected visual acuity in his left eye of 20/70 and he was fixating eccentrically. He also had a 5-degree visual field defect on his Amsler grid. Slit-lamp examination was normal, and the right eye was completely normal.

Six months after his initial presentation, he was unchanged. During that interval, from October to March, he had been taken out of the laser environment, so he had no laser exposure. He was seen again 1 week ago and was found to have a lesion in the right eye also. At that time he had 5-degree scotomata. The scotomata fluctuated from 20/70 up to 20/400, depending on who was examining him.

I think that these two cases typify the potential problems that are faced by those of us who are responsible for establishing the guidelines for surveillance of laser workers and others who are potentially at risk to laser exposure. Namely, what is needed is to establish standards that have both sufficient strength and flexibility to protect those who might suffer from laser trauma unbeknown to themselves, and also to discover those who might malingering or abuse the system for whatever purpose.

In conclusion, questions arise which must be addressed by groups such as this. What warning must be given to those personnel who are potentially at risk? What are the most important examinations to be performed on these personnel? Can they be performed easily with available field personnel at onsite facilities or is it necessary to send people to large centers to conduct these examination? What equipment is necessary to add to the screening examination for these personnel? What tests are most likely to yield reliable and reproducible results? Which ones are most efficient and cost effective? Which ones represent overkill, in that they are extremely costly, esoterical from the clinical perspective, and, worst yet, are not really specific enough to tell you answers to the questions that you need to know? Hopefully, this group will resolve some of these issues. Thank you.

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DISCUSSION

COL Whitmore: In the last case (the electrical technician), what was the age of these lesions?

CAPT Wolfe: The electrical technician was seen in October; at that time he was referred from the test before the field exercise.

CAPT Blaise: Were any of these lesions in the pigmented phase?

CAPT Wolfe: That is a good question. At that time, some were lightly pigmented.

COL Whitmore: Were these raised lesions?

CAPT Wolfe: No, they were not.

COL Whitmore: Except for the linear pattern of these lesions, they could be drusen. They are so concentrated and so peculiar in their orientation. This is a classical example of the clinician's problem. It shows our real dilemma.

CAPT Wolfe: The appearance is a typical, except perhaps for Best's disease, but my impression is that they do not look like Best's. It would be good to know if any of these evolved into the pigmentary stage.

Dr. Wolbarsht: The first question to pose without even seeing the charts is whether a patient would have any motive for altering the facts relating to an alleged exposure. We have looked at many case reports, including ones not presented here, and have come to the conclusion that most were the result of deliberate staring into a laser beam. One should always ask whether the person's exposure was, in fact, in agreement with clinical findings. Perhaps the Napoleonic Code should be invoked here: The patient should be considered as having stared into the beam unless he proves otherwise.

Dr. Tengroth: In my experience I have seen a number of cases like this where the patient had never even seen a laser such as this one. These lesions have nothing to do with lasers, and the patient you showed after this one had probably never been exposed to laser beams either. Many of the cases in the literature (I think I saw the Zweng case personally) were not laser-induced lesions either. There are a number of these reported cases that were also not laser-induced lesions. The problem lies in the ophthalmologist who examined each subject, with regard to the published reports. You know that many of these clinicians were not retinal experts when they were involved in the laser accident examination. Even Meyer Schwickerath, when he was developing the first retinal photocoagulator, did not always recognize forms of diabetic retinopathy. The lesions in the electronic technician are not symmetric in both eyes as would occur with laser exposure.

COL Whitmore: You mean the clusters were both temporal. I have seen a few of these cases, and it is very awkward to make a diagnosis.

COL Tredici: We are losing sight of the fact that there was a breakdown in the system. The rules were not followed. It is immaterial what the lesions are. If the procedure was done properly, the patient would not have to be cleared for laser work. The technician would have photographed him, and I would have reviewed the photograph within the next day or two. This is the purpose of preplacement screening.

CAPT Wolfe: Would you photograph him and then bring him back for a detailed examination?

COL Tredici: Any photograph that is not normal leads to reexamination by the ophthalmologist. That is, out of 25 examined, over 24 are approved for work. The 25th would not be placed into any laser work until the problem was resolved. This problem should not have come after the laser field test.

CAPT Wolfe: Yes, you are right, it did come out after the fact.

COL Tredici: They did check him before he was out on the range, and he had already been working there since 1974.

CAPT Wolfe: In 1978 he had what was reported as a normal fundusoscopic examination.

Dr. Wolbarsht: Furthermore, he told you that he had had an accident. He had an exposure, but he said he did not have any visual problem from it.

COL Tredici: This brings out a new disease, "scientist's disease", if I may be facetious. We all know that scientists have a total disdain for safety. The incident related by the Army tank commander made a specific point that he was following the guidelines, but a lens fell out of his laser protective spectacles, resulting in a possible exposure.

LTC Pitts: In the case of the Army sergeant, there are extenuating circumstances, including a pending court-martial and family problems which could influence the patient. We could not actually find records that the patient had ever participated in the test in the particular vehicle to which he referred. No other test participants or the noncommissioned officers in charge of the vehicle or test records could substantiate his story as to having been in that particular vehicle.

Dr. Tengroth: Today, the laser is employed clinically to treat diabetic retinopathy, retinal tears, etc. In a number of these cases, accidental exposure of the fovea has occurred and has been reported. From these cases, we know actually what a laser lesion looks like ophthalmoscopically in a human, which is not the same as in the rhesus monkey or a rabbit. I think one should search through these reports, and then we shall clearly see the difference in the ophthalmoscopic picture. The cases reported as occupational laser accidents are very different. They do not look like

the clinical accidents. We now know quite a lot that we did not know when Zweng reported his laser accident cases. We know what photocoagulation from different kinds of lasers looks like in the human retina.

Mr. Sliney: I believe that there have been a number of instances where laser workers have thought that they had incurred laser-induced injuries when, in fact, they had not. One scientist, who could not remember having seen a flash of light when working with a visible pulsed laser, experienced a visual loss and reported to an ophthalmologist who saw what appeared to be a spontaneous retinal hemorrhage. The circumstances were such that I do not feel that he could have been exposed to a dangerous laser beam. Dr. John Marshall of the Institute of Ophthalmology (London) told me of two similar cases where he was absolutely convinced that they were spontaneous hemorrhages--not the result of laser exposure as the British workers alleged. I gather from him that the patient should be watched to see if another spontaneous hemorrhage occurs.

To convince a laser scientist that these did not result from laser radiation is almost impossible. Giving laser workers eye examinations and educating them about laser hazards to the retina presents a new problem. If anything happens to the retina, it is almost impossible for the patient to believe that it did not result from laser work. Indeed, it is sometimes very easy for the examining eye specialist to believe that the retinal pathology resulted from laser exposure, since he is often examining an individual because of a laser surveillance program. Another point that I wish to make is that it is very important when reviewing an accident case to remember two things:

First, it is extremely difficult to make an estimate of what the exposure dose is, because of the low probability of a tiny pencil beam entering the pupil of the eye. An exception would be the case of the reflection off the coke bottle where the victim was probably exposed to a very large beam. It would be extremely difficult to calculate within a factor of 10 the exposure dose to most accident victims. What is of value in this collective review of accidental injuries is that all of the estimates are around the milliwatt level, which is probably realistic.

Secondly, these studies remind us that the person who is injured or allegedly injured had something to lose or gain by the findings. Many people have come up to me at the end of a laser safety briefing, over the last 10 or 15 years, and quietly stated that they had experienced a laser injury. In each case it occurred because the person did not follow safety rules, and in each case they never reported it because it was too embarrassing to admit that they were not following the safety rules. Since they could see very well, they felt that they had nothing to worry about. Each told me, I guess, since they wanted to know if there was any likelihood of delayed effects. I would always say, "As far as we know, based upon present knowledge, you should not have to worry about delayed effects, but you should have a funduscopy examination periodically." I concur that there are cases where people will not report the injury and then change the

story to make it appear that they did nothing stupid. The best example of this was reported in Laser Focus a few years ago. A technician in Florida claimed he had been wearing laser goggles when a reflection entered the crack where the goggles fit the face. I received many phone calls after this report, because I had often argued in laser safety courses that tight-fitting goggles were not essential. I explained to the callers that the printed report was surely in error, since a central macular lesion could not have occurred unless the eyeball had come out of the socket and turned downward to look through this crack. Clearly, this was an example of the patient's not wanting to admit that he was not wearing his goggles. One must be extremely careful in drawing any very firm conclusions in any given case. But, collectively, I agree that these reports give a general picture. The question I have for CAPT Wolfe is whether one can rely upon an exposed individual's being aware of the exposure and, therefore, reporting it. In any of the confirmed laser injury cases that you reviewed, was the patient unaware of the occurrence of an injury prior to the ophthalmic examination?

CAPT Wolfe: I think the case that comes to mind is the one Boldrey reported, where another lesion was present in the other eye.

Mr. Sliney: And the patient did not realize it?

CAPT Wolfe: This was the only one not detected at all. In all the other accident reports, it was quite clear that the lesion was known to the injured party.

Mr. Sliney: This factor is important in determining whether there is any need for periodic examinations.

CAPT Blaise: In the Curtin-Boyden case, the individual supposedly was aligning the laser with his safety goggles up on his forehead. This was probably not published in the original paper, but upon reviewing the case records, this becomes apparent. Considering the depth and degree of this lesion with this type of laser, the reported scenario was viewed with suspicion from the beginning even though the case was reported as if it had been a real accident. We know today that a severe retinal disruption, and a severe burn, would have occurred with changes that would go deep into the sclera. By inference we know that this would not have been a burn by a reflected beam.

COL Whitmore: Mr. Sliney brought up a very important point in this discussion: the question of long-term effects on the exposed individual. I do not think that we can claim to know the long-term effects on this individual patient. We do not know what damage occurred to Bruch's membrane. Such damage may result in subsequent disciform degeneration in the region of the lesion. I do not think we can be certain of the long-term effects until we have sufficient chance to observe them.

Dr. Wolbarsht: Actually the point you just made is a very important one in relation to what Mr. Sliney said earlier. There have been cases where individuals working with lasers have had unrelated disciform macular degeneration. The individual often blames the deterioration of vision on laser exposure. This then becomes a clinical problem when explaining to the patient that laser exposure may be the treatment for the problem they have. Of course, the diagnosis is simple, but the patient is convinced that occupational laser exposure caused his visual loss.

COL LaPiana: I wish to make some clinical points in an attempt to clarify what we are discussing today. We shall discuss these later in greater detail. First, there is a variation in the structure and appearance of the foveola, one of the most important structures of the retina. The appearance of the fovea and foveola varies with age and race. Second, fundus photography remains an art and not a science. The clinical photographs presented today can demonstrate or not demonstrate almost anything depending on how the photograph was taken. Third, even the best 2 x 2 slides fade and change with time. Fourth, patients who have been exposed either accidentally or intentionally or who have stared at the sun will quite frequently malingering regarding their visual acuity. The ophthalmologist treating this type of patient must be quite circumspect in the method used to measure visual acuity.

COL Ranadive: In relation to your statements and those of Mr. Sliney, I have four questions. First, can we just depend upon reported symptoms to replace screening? Second, would visual screening examinations taken before an exposure and after an exposure determine a change in visual acuity adequate for our purposes? Third, with reference to CAPT Blaise's comment for those cases of known laser lesions, how many have been followed for long-term effects? Fourth, for COL Tredici: Do you now require that all individuals that are participating in laser programs within the Air Force receive fundus photography?

COL Tredici: Well, I will tell you tomorrow. We are still in the evolutionary stage. Initially, we performed almost every known test - "the big \$2,000 examination" - which seemed like the right thing to do at the time. However, a manpower shortage soon forced us to reduce the extent of the examination.

MEDICAL-LEGAL ASPECTS OF SURVEILLANCE EXAMINATIONS

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The Government has to be concerned with two types of compensation in this area. The first is under the Federal Tort Claims Act, under which service personnel and civilians will try to take the Government to Federal Court. From this, you encounter the large million-dollar judgments, malpractice suits, and personal injury claims. The second type of compensation is through the military/civilian disability system. There are big differences in the two. Generally, the compensation one receives through disability will be far less than one would receive in Federal Court, since one can sue there for pain and suffering, and a spouse can sue for loss of consortium, and may receive much larger judgments.

Prior to 1946, no one could sue the United States Government. This was based upon the European Doctrine of Sovereign Immunity which precluded a king from being sued without his consent. In 1946, Congress enacted the Federal Tort Claims Act and consented to be sued for personal injuries or death caused by a Federal employee acting within the scope of his or her employment. However, there is an exception: One cannot sue the Government for assault, battery, libel, or slander by a Federal employee. In 1950, the United States Supreme Court made an important interpretation of the Federal Tort Claims Act. In that case, three servicemen tried to sue the Government while on active duty. Two sued for malpractice based on alleged negligence of military positions, and the third sued for wrongful death of a serviceman who was killed in a fire due to a defective radiator. The Supreme Court said that active-duty servicemen could not sue the United States in Federal Court for wrongful death or personal injury when the wrongful death or personal injury was incident to their service. The Court gave several reasons. The two main ones were that, as veterans, they would have a disability compensation and if serviceman could sue his or her military superior for ordering him to go into battle, or for anything else, this would erode the military system. "Incident to service" has been expanded to cover every situation where the serviceman is on base even if not actually on duty. The exception would be by example: two servicemen involved in a car accident offbase - one is on military orders, the other is not. The one who was not on duty could not sue the Government for the negligent act of the other, because that serviceman was not on base. Thus, the act was not "incident to service." On the other hand, if the person is in the barracks, anywhere on the base, on a ship, even sleeping, and not on duty, it is still considered "incident to service." A plaintiff would be barred from going into Federal Court. This is known as the Ferris Doctrine.

Another important exception would be if a military person had incurred an injury while in the military and later that injury were aggravated in a Veterans Administration Hospital, that person can sue the United States for the aggravation of the injury.

There are no actual recorded cases involving laser radiation. Therefore, I shall review analogous cases of other types of radiation. Servicemen are constantly attacking the Ferris Doctrine to obtain a bigger judgment. In a very recent case, *Brodie vs the United States*, the plaintiff's husband had served as an officer in the Marine Corps from 1944 to 1960. During the summer of 1957, he was ordered by his commanding officer to participate in military exercises in the vicinity of two Nevada atmospheric nuclear tests. He was discharged in 1960, examined at Marine Corps medical facilities. In 1976, he was diagnosed as having a form of cancer which has been related to low-level radiation exposure. He died in 1977. His widow sued the United States Government under the Federal Tort Claim Act for wrongful death and alleged genetic damage to their children. She stated in her claim that the Government knew that the exposure to radiation would cause cancer; that they failed to inform him that these maneuvers involved any potential health risk; that he was not given an opportunity to decline to participate; and, finally, that after he was released from the service the Government was negligent in failing to warn, monitor, or treat him for any aftereffects of this radiation. The Court held to the Ferris Doctrine, which prevented her from suing under the first two claims: that he had been ordered to participate in these maneuvers, that he had not been given a chance to decline, and that he was not warned of any danger. He was on active duty, and all of these events were incident to service. However, she did have a cause for action for the third claim. The Court said that once he was discharged and the military discovered that, perhaps, there were men exposed to radiation and likely to have problems, he should have been warned and monitored. Thus, she was allowed to recover.

Another similar holding can be found in *Everette vs the United States*. In that 1980 case, the plaintiff's husband participated in military maneuvers held in 1953 in conjunction with Nevada nuclear weapon tests. He died in 1977 and his widow claimed that her husband had been ordered to march through a nuclear blast area less than an hour after detonation of a nuclear device. She claimed that the military did this for the sake of experimentation; that this was willful, wanton conduct; and that they wanted to experiment with her husband and other servicemen to determine the effects of radiation. She argued that because the Government's conduct was willful and wanton, she should be allowed to recover from his death. Although the Supreme Court stated that it did not like the Ferris Doctrine, it was bound by it. The Supreme Court's decision was that she could not sue the military for not warning him or for ordering him to participate. However, as in the first case, she was allowed to sue because, after he was separated from the service, it had not warned him of the dangers and then monitored his condition.

There has been a different ruling in the Agent Orange cases. Thousands of Vietnam veterans have sued the manufacturer of Agent Orange. The manufacturer sued the Government, in turn, for indemnity. Although a service member cannot sue the Government, he can sue the manufacturer of machines or chemicals if there is a defective weapon or machine involved. In any laser injury, the injured party cannot sue the Government but can

sue the manufacturer. For example, there have been many cases where manufacturers of x-ray machines have successfully been sued for defects in their machines which resulted in excessive emissions. The Court has said that the manufacturer of Agent Orange cannot, in turn, sue the Government for indemnity if a serviceman, himself would have been barred from suing the Government. In this case, the chemical company argued that the Government failed to warn the veterans that delayed health problems may result from having been exposed to Agent Orange. This would allow the veterans to sue the United States Government, but the Court did not accept this argument of the failure to warn after they were discharged. The Court felt the health problems really arose from duties in the service.

One of your considerations should be to clearly warn laser users and to establish liaison with the Veterans Administration to monitor for delayed effects. However, other than the factor of failing to warn veterans of delayed effects, it is clear that active duty service members are barred from suing the Government in Federal Court if injured by laser radiation when ordered to participate in war games. They cannot sue their superior officer or the Government. Their only recourse would be through the military disability system where the amount of money will be much less than in Federal Court. If a service member, while on active duty, makes a claim for injury, the burden of proof is on the Government to show that this injury was not caused by military service. The servicemember will be given the benefit of the doubt. That is important for him to realize. The first consideration, then, is whether the person actually sustained a service-related injury. The second consideration is whether the serviceman with such an injury, though having less visual acuity, is still qualified to perform the duties of his or her military occupational specialty (MOS) or another MOS for which he or she qualifies. If the degree of visual impairment does not disqualify the soldier from performing the duties of his or her office, grade, rank, or rating, he or she will be denied any disability payment. Even the fact that the soldier never had to wear glasses previously, but as a result of the injury now has to wear them, is immaterial. On the other hand, if the person's visual loss is such that he or she absolutely cannot perform in his or her MOS or in any related field, it must then be determined if the injury was incurred in the line of duty and not from the person's own misconduct.

Some examples of misconduct would be the intentional pointing of the laser into one's own eye, horseplay, and injury resulting from being drunk on duty. In these circumstances, no disability payment could be recovered. However, if it was in the line of duty and not due to their own willful misconduct, payment will be made. The Federal Compensation Act has language in the statute which states that, for civilians, the Act is the exclusive remedy for injury. They cannot sue in Federal Court under the Federal Torts Claim Act. Because of this language, far fewer civilians try to sue in Federal Court, whereas military plaintiffs often try to sue by attempting to have the Ferris Doctrine set aside. Unlike the military, civilian employees can recover for loss of vision even if the loss is minor. They will not be paid very much; the scale will depend upon the employee's salary and the American Medical Association guidelines for the percentage of impairment. Therefore, it is even more important for civilian employees, to be tested before and after being exposed to lasers.

There are not many reported ophthalmic malpractice suits at the Armed Forces Institute of Pathology (AFIP). There is one case of Helen vs Carrie. In this 1974 case, a woman, initially 22, visited two physicians over a period of 10 years and complained of eye irritation. The doctors repeatedly told her over this 10-year period that the eye irritation was due to wearing contact lenses. Over the 10-year period, they did not perform tonometry. Ten years later, they finally performed the intraocular pressure test (tonometry) and found glaucoma. By that time, her vision was severely impaired. Two medical experts at the malpractice trial testified that the standard of care was not to routinely perform tonometry on a patient under the age of 40. These doctors did not think of this as malpractice, as the ophthalmologists had followed the standard of care. Although the experts' testimony normally would be controlling, the Court disregarded this testimony and found the doctors liable for malpractice. The court's reasoning was that a safe, simple, and inexpensive way of testing for glaucoma was available. The Court ruled that the standards of care did not apply in this case. I think that any attorney representing a civilian or military employee claiming laser-related disability will first argue that the person should be given the benefit of the doubt, and, secondly, the attorney would probably point to this case and say that a safe, simple way of testing existed and was not performed.

I think you should definitely have written guidelines for the person performing the examinations. Under these guidelines, the examination should include as many tests as feasible. You should also consider those areas where the Government could be liable in Federal Court, such as the failure to warn at a later date.

DISCUSSION

COL Ranadive: You made a very interesting point: the failure to warn; but more important are the requirements to follow the exposed individuals. With regard to laser exposure, followup may not be considered important because many of the attendees here think that laser eye injury does not have long-term implications of future aggravation of functional or structural damage. But when one is facing exposure to carcinogens of any kind, I become worried. What concerns me is the difficulty of getting the Department of the Army to set up a very complex monitoring program which will require considerable resources for such a large population. Which United States Government agency should initiate such a program and take on the responsibility for administration? I would like to talk to you further concerning this, as it is a question we need to address.

CPT Stout: At this point in time we do not anticipate delayed effects. An acute laser injury should heal without particular problems. To what extent should we as professionals document either the effects or lack of effects from the legal standpoint?

Ms. Norman: Definitely, with regard to the Agent Orange study, the Veterans Administration is having a hard time proving or disproving whether Agent Orange has caused the symptoms being reported by thousands of Vietnam veterans.

COL Tredici: The fallacy I found in the legal points you made today is that this could have been anticipated or there is a substantiated cause-and-effect with Agent Orange. This same problem relates to the two individuals who developed cancer long after the atomic bomb tests, through which 4,000 other troops marched but have not reported any problems. In a normal population 2 people out of 4,000 will get cancer anyway.

COL Ranadive: The question of how many people will contract cancer after nuclear tests is an interesting one, but let's return to the subject of lasers and laser surveillance.

COL Tredici: I just wanted to make the point that there is a great problem in separating delayed effects from naturally occurring effects.

COL Whitmore: I would like to indicate that I am not at all certain of a lack of delayed effects. I would like to poll the ophthalmologists present as to their opinion of delayed effects in light of the amount of damage that might be done to Bruch's membrane by laser exposure. Does everyone feel comfortable that there will be no long-term effects?

COL Tredici: The problem of determining long-term (delayed) effects is that age cannot be divorced from them. All of the effects discussed today: cataracts, Bruch's membrane difficulties, senile and presenile, changes, occur with and without laser exposure. I see no way to determine the etiology in a given case.

COL Whitmore: My point is that a laser injury does damage Bruch's membrane and, thereby, potentiates the possibility of delayed clinical problems.

CAPT Wolfe: I would like to strongly echo what COL Whitmore just stated. I think it is well documented that neovascularization can follow laser photocoagulation in the macula. I think that the accident victims who had retinal hemorrhages are particularly at risk of developing this problem, because they do have defects in Bruch's membrane.

COL Tredici: But the victims are normal. The therapy patients to whom you refer had abnormalities to begin with or they would not have been treated with the laser. A young, normal individual who receives an acute laser injury may not have these secondary problems. The accident victims must be carefully followed to answer this question of delayed effects.

COL Ranadive: Returning to the point of medical-legal liability: What steps should the Services be taking at this time? We clearly do not know if there are delayed effects from laser injury. A group of you will have to decide if a study of this problem is worthwhile; what kind of injury studies should be done and by whom; and, once there are findings, to inform those individuals who suffered acute injuries.

Dr. Wolbarsht: I just wish to say that it would seem somewhat difficult to maintain that damage to Bruch's membrane from a laser would predispose the subject to the formation of disciform maculopathy, because that is the way one treats disciform maculopathy.

COL Whitmore: We are referring to reports in the literature of this pathology following laser treatment. My major point is that we should not go on record as saying that there are no long-term effects.

COL Ranadive: The next question is: what should the examining physician tell the laser injury patient? More importantly, what long-term followup examinations should be performed? Furthermore, of what should a long-term monitoring examination consist? As soon as we have an alleged injury, where in the Army should the patient be examined? Do we send him or her to one place because only one person is expert?

Dr. Tengroth: Are we speaking of an absurd workload? So far, we have been talking about only laser lesions of the macula, at least 17 reported by ophthalmologists. Now calculate from that there might be thousands and thousands of unreported peripheral laser lesions. What are we going to do about these people? Every person exposed to a laser can always say he was exposed to a laser beam and has a lesion in the far periphery. There would be no ophthalmologist who can tell if these lesions are from a laser or abnormalities of another kind. There are a number of abnormalities which occur in the periphery. I would like to agree that one cannot make any statements whatsoever about delayed effects. We are in a much more difficult situation with our inability to diagnose accurately acute laser burns of the retina. A patient must appear immediately following a laser eye injury to aid its proper diagnosis. Only following clinical laser photocoagulation can one state with certainty that the lesion was caused by a laser.

COL Ranadive: I see two questions. First, following an accident, whether a diagnosis of laser induced retinal injury can be accurate with diagnoses from clinical pictures and an historic background. Second, whether and how should these individuals be followed, and with what kind of followup.

Dr. Tengroth: What is the reason for following the patient? Do we wish to determine if he gets worse? If his vision degrades, would he not approach us anyway? Even if he appears 10 years later, we cannot state that the visual loss was or was not caused by the laser lesion.

COL Ranadive: The only reason I can determine for following such an individual is to gain epidemiological knowledge, but here I enter onto thin ice, since this is not my area of expertise.

COL LaPiana: Another very real and practical medical administrative objective in this situation is to place patients with progressive disease in the temporary disability retirement system, and not in the military retirement system. This would permit them to be compensated during the period of followup.

Mr. Sliney: If I understand this discussion correctly, the important medical surveillance procedures must be performed immediately after the accident. There seems to be agreement that for good documentation the time course of the lesion must be followed for several days afterwards, because the lesion's appearance goes through certain stages that permit one to distinguish it from other etiologies. From the medical-legal discussion, the individual must be informed of this effect and it should be explained to him that he should be monitored from time to time because of the present inability to make a final prognosis. This would take care of the medical-legal requirements, as I understand them. This suggests that there is very little medical-legal justification for wholesale eye examinations of personnel leaving Government employment, as they would have reported any functionally important lesion. Is this an accurate summary?

COL Ranadive: Does everyone agree with the implicit assumption that the patient will notice accidental laser eye injuries and seek medical care and be properly diagnosed?

Dr. Tengroth: I have personal experience with one case of intentional laser exposure. A man scheduled for enucleation because of maxillary sinus cancer was exposed to a relatively low-energy pulsed ruby laser in 1964 at a distance of about 150 m. The man reported only a weak light flash and no pain or any other signs. After exposure, visual acuity dropped from 20/20 to 20/200 and after enucleation, it was revealed that the patient had suffered a macular hemorrhage. I do not believe that a patient would necessarily connect the symptoms with a laser exposure. Therefore, I do not think that an individual would intentionally cover up a laser accident. The cases reported by CAPT Wolfe were reported as accidents, because people actually had looked into the laser. We have not had cases, to my knowledge, where accidental exposure occurred and the patient was unaware of the cause. I do not believe that patients will think to say if they have been around lasers on the day of visual loss.

COL Tredici: I have two comments to make: From this discussion, it is clear that we do not have the answers to the questions generated by the delayed effects in normal, healthy eyes from laser burns. No one will voluntarily subject themselves to a laser exposure to determine delayed effects 20 years later. However, there are 18 accident cases which could provide an insight if the patients were followed. The first accident occurred 15 years ago; the next, 14 years ago, etc. Thus, we can begin to collect data by a protocol already there and monitor all 15 of the accident victims. If none of them develop an ingrowth, that question will be answered. Second, we check everyone when they leave the service. We have many people who serve for 2 or 3 years and then move into technical jobs with Philco, Raytheon, etc. Those people do not always receive a new examination at their future workplace. Should they be injured in their new place of employment, we would have no documentation to refute false claims, so we still provide a final examination as needed.

Dr. Tengroth: A number of other cases consist of photocoagulation of macular holes, retinal detachments, and other parts of the retina where there are no vascular disorders. These exposures from lasers date back to 1961. We have had no reports, whatsoever, of any progression as far as I know. We should have heard of such from some of these cases by now - 20 years later.

COL Whitmore: You were speaking of properly applied energy levels in a clinical setting, but here we are talking about potential thermal damage to Bruch's membrane in relation to a laser injury. Lately, we have noted in our literature that a risk of ingrowth does exist. Considering these factors, I do not think we should say that we do not believe in any long-term delayed effects.

Dr. Wolbarsht: There were several volunteers who had laser lesions placed in their eyes. I think several who worked with Dr. Chris Zweng volunteered and these individuals are still around.

CAPT Blaise: With respect to the Curtin-Boyden case, I noted this morning that there was neovascularization with some fibrous ingrowth and a little wrinkling of the retina adjacent to the hole. From fluorescein angiography and color slides, there have been essentially no changes detected at the exposure site from 1970 through 1982. In the last 2 months, I have reviewed the entire past history of this case. In this one case, (Curtin-Boyden) we have the entire history.

Mr. Sliney: We need to return to the basic problem of the number to be examined. If everyone potentially exposed to lasers in the military should require a termination examination to medically-legally protect the Government, everyone in the Army must be thoroughly examined within a few years. This is a serious problem to resolve. We cannot examine everyone. I think one must select a group where there is the greatest likelihood of injury. Is that what one wants to do? Should only those who have reported injuries be monitored?

COL Ranadive: We appear to have two unresolved questions:

(a) We have not put to rest the question of long-term delayed effects from acute laser eye injury.

(b) We need a policy for those individuals who have never complained of or had a documented laser eye injury and are terminating employment.

The first question may be answered by the followup for X number of years of the cases just mentioned. Hopefully, in a few years, one may be able to state confidently that a given type of acute laser injury will have a known set of sequelae.

Second, with regard to termination examinations of laser employees, I for one would propose that the basis be a functional test of the employee's vision, rather than concentrating on the structural aspect. It would be sufficient to test visual acuity and perhaps other visual parameters that can be tested functionally.

CAPT Blaise: I believe that every service routinely provides a termination physical that incorporates a measurement of visual acuity. An abnormal visual acuity should result in a fundus examination, and any significant laser burns should be revealed at that time.

COL Ranadive: A few years ago separation examinations were elective for the individual. Since then, the Veterans Administration told us that these examinations are essential and should be mandatory to permit a valid assessment of a veteran's claim. These examinations are, therefore, now a requirement.

Mr. Moss: Just how large is this problem? How many individuals in the service are potentially exposed and who would need examination?

COL Ranadive: Dave?

Mr. Sliney: Within a few years, every soldier in the Army will work with lasers in one task or another. I would not guess there to be large number of technicians and scientists.

COL Tredici: Up to now, only a small number of technicians and scientists worked with lasers, a number readily examined, but it sounds like we shall be seeing an impossible number (300 to 400 thousand) for examinations within a few years. Next, we shall hear that with MILES the soldiers will have lasers in their barracks.

MAJ Mathewson: I have a question for Ms. Norman on the legal aspects. If this body reaches the conclusion that delayed, long-term effects are possible, but cannot agree on a valid followup examination of individuals with alleged injuries, what is the Army's legal obligation to follow up any soldier's alleged injuries.

Ms. Norman: As I explained before, the Court decided that in the case of the atom bomb test the failure was not that the soldiers were ordered to march into a radiation area, but in failing to warn of delayed effects and the need to monitor them.

MAJ Mathewson: This is a different situation. It is not so much a failure to warn them but, now that we agree that there may be long-term effects, is there an obligation now to answer the question of whether there really are delayed effects?

COL Ranadive: That is a good question, but it is third priority to the questions of the examinations themselves. Perhaps this should be discussed in the panel tomorrow.

Mr. Moss: With regard to Ms. Norman's point of informing on delayed effects, wouldn't it be more cost effective to give every soldier a comprehensive eye examination when he leaves the Army?

COL Ranadive: This might be desirable, but one must remember that there are many occupational hazards, and the occupational health budget and manpower are not limitless. Thus, we must accept a certain burden of professional judgment, as long as it has a scientific basis. If history proves us wrong and compensation must be paid, then so be it.

COL Tredici: This is why we favor terminal examinations.

VISIBILITY OF RETINAL LESIONS

(Panel Discussion)

COL Ranadive: I now invite the members of the Panel on Visibility of Retinal Lesions to come forward and take their positions. Each panel member will be given up to 15 minutes to present his position, then the subject will open to discussion. Dr. Bjorn Tengroth, Karolinska Institute, Stockholm, Sweden, will be the Chairman.

PANEL DISCUSSION

Dr. Tengroth: The first question that I would like to put to the panel is: From the ophthalmologist's point of view, can one really distinguish a laser lesion from other pathologies by ophthalmoscopy? The ophthalmoscope is a good instrument, but difficult to use. Nevertheless, it is astonishing --when comparisons are made between ophthalmoscopic and histologic findings in exposed rabbit and monkey retinas--just how much we can see. But the question is not whether we can see something, but whether we can know what we are observing--what kind of lesion it is. It is my view that it is almost impossible to determine whether an observed retinal lesion or scar is the result of exposure to nonionizing radiation. I have never been able to make such a determination. I have seen a number of scientific papers where authors have described "a typical laser lesion." There is nothing that is unique about a laser lesion for obvious reasons. The appearance will differ, depending upon the energy and power level, the retinal area exposed, and the wavelength. Therefore, as an ophthalmologist, I cannot say that a specific lesion was caused by a laser, unless a patient walks into my office, describes a laser exposure which occurred within the last couple of hours, and states that he sees visual defect. If I follow the lesion's appearance for the next few days and I note epiferation of that scar, hyperpigmentation and atrophy, I could agree that it was probably caused by a laser beam exposure. However, if the same patient were to come to my office for the first time 2 months after he or she claims to have been exposed to a laser, I may observe a few unusual white lesions or hyperpigmented areas. If I see them in the macular area, I am fortunate, but if they are located in the periphery, I would be unable to say anything. The worst situation occurs when I am presented with a patient absolutely healthy, in fine physical condition, but the macula looks terrible. And yet he has 20/20 (6/6) vision! But with no loss of function there is no problem.

I might have a case where I am treating a patient with a laser in the perimacular area and, upon eye movement, the patient is exposed close to the foveola. He has normal definition, normal Amsler grid chart, normal electrophysiology, normal color vision, and since the patient has a laser lesion (I know because I placed it there), it illustrates that function has little to do with the appearance of the macula, and vice versa. One may encounter a patient with eccentric fixation. We know as ophthalmologists that eccentric fixation does not result from a laser lesion; most probably, reduced vision is generally present at the age of 5 or so with amblyopia.

So, when we review the published reports of "laser injuries," we ought to conclude that some of these cases are obviously not laser lesions.

Another point I wish to make relates to a sensation of pain. I mentioned previously the case where the individual reported seeing a bright flash, experiencing a sharp pain and now cannot see anything; that is also not a laser injury. I have photocoagulated a number of people with a laser, and it is not half as painful as was the old xenon-arc photocoagulator. The shorter the exposure, the less they knew about it. We, therefore, should be wary of an individual claiming he was exposed to a laser unless he was looking straight into it and for some reason it went off.

In my mind there are three problems:

- (1) distinction between laser induced lesions and other pathology
- (2) morphology versus function
- (3) the lack of understanding of visual effects versus laser exposure, which leads me to the conclusion that there is no ophthalmologist today who can answer the question of whether a person was really exposed to a laser beam, or if a given retinal pathology is surely due to a laser. That is the state of the art; I am sorry.

Dr. Zaret can answer a number of questions: the origins of cataracts from one nonionizing radiation source or another. But one cannot make such a determination there either.

Now Dr. Ham will tell us about experimental laser lesions. I presume, Dr. Ham, that you can tell us that patients do not complain about laser lesions.

Dr. Ham: I will be careful what I say with an ophthalmologist sitting on each side of me; all I know about is monkeys.

Dr. Wolbarsht: That's what the Army needs.

Dr. Ham: As you know, Mr. Harry Mueller and I have used rhesus monkeys for laser retinal studies for a number of years. So, we have a few things to say. At the onset, I should like to say that all of the lesions about which we have been speaking this morning can probably be classified as thermal lesions. In one case, the Q-switched laser-induced lesion, one might say that the damage is thermoacoustic, and some damage is the result of an acoustic transient. But, I think most of the cases reviewed by Dr. Wolfe are largely thermal. Would you agree Dave?

Mr. Sliney: Yes, they are thermal and thermo-acoustic. We are not talking about the photochemically induced "blue-light lesion" which results from lengthy exposures.

Dr. Ham: In our experience with lesions produced, for example, by the Nd:YAG, 1064-nm laser, imaged on a 500 μ m diameter spot, the size of the thermal profile is at least 500 μ m, but my technician, having become adept, can produce a lesion of only 30 μ m diameter, corresponding to the central and hottest spot of the area being irradiated. This is clearly thermal in nature. It contrasts with our experience with the blue-light lesion where the lesion's borders correspond to the irradiated area. In our limited experience with sonic transients and also with picosecond pulses, damage at threshold is very limited. The damage is presumably initiated by a sonic transient in the RPE around the melanin granules, but does not progress very far. The damage is normally localized in the RPE and the outer segments of the receptors cells.

I agree very much with Dr. Tengroth that one cannot identify a retinal scar as having been laser induced. I know of no way an ophthalmologist could identify a scar as having such a unique origin.

CAPT Wolfe: I really have little to add. I agree with Dr. Tengroth that it is impossible to visually examine the macula and predict the visual acuity. It is very impressive to observe ophthalmoscopically what appears to be a normal, settled macula, and yet how disturbed the vision may be. The opposite is also true.

Dr. Tengroth: We might add to this that even with fluorescein angiography, the picture may appear normal, and yet visual function is poor.

Dr. Wolbarsht: There are some points that might be added, without exactly disagreeing with what has been said. One problem with collecting data from accident reports is validating the story, but in fairness we now know quite a bit about laser bioeffects, and we can sift some of this information. For example, in the case of the lesions eccentric to the macula where the patient has eccentric fixation, it might be suggestive that the patient was looking at the laser with that eye. If the lesion only occurs in the dominant eye, this is also suggestive. If a person reports he was exposed to a He-Ne laser (633 nm), is experiencing pain, and examination shows corneal damage, we know that was not caused by the laser. These are examples where some degree of experience can aid in interpretation. I suspect that thermal damage from an argon laser will look different from that of a ruby laser and especially from a neodymium 1064-nm IR laser.

Dr. Tengroth: The histology looks different, but 2 weeks later the ophthalmoscopic picture are the same.

Dr. Wolbarsht: But, you spoke of following the history of the lesion. That is a major aspect of the process. It is true that a patient claiming belatedly that a retinal lesion was the result of an undocumented field laser exposure incurred 2 years previously should be viewed with suspicion. The retinal appearance could not prove the point. But, if, immediately after a field exercise, a soldier comes in with a story of an incident where he was exposed to a target designator beamed from across a valley, you can follow the history.

Dr. Tengroth: I have a story that may have some bearing on this. A few years ago, a clever ophthalmologist in Sweden came to me, explained that she had two patients with very typical laser lesions of the macula, and asked me to examine them. I expressed my doubt that she could attribute them to lasers. She said "Oh, I am quite sure they are laser lesions because they have been working with radar." "Oh," she said, "that's right; they are microwaves; they are small aren't they?" This led to an investigation of about 30 persons working with microwave radar. It was revealed that all who had been exposed had been looking straight into microwave waveguides at very high power densities. We still cannot confirm that these retinal lesions were the results of microwave radiation, which is not really focused by the optics of the eye, but there may be a "hot spot" near the retina due to an interface problem. The wavelength was 24 cm (1.25 GHz). We told the workers that we were unsure of the relationship to microwaves, but it stirred up controversy in this country. Dr. Zaret, in particular, took note of this. I present this story to illustrate what can be described as a "typical laser lesion" by a competent ophthalmologist. This illustrates the state of general knowledge.

Dr. Wolbarsht: In the early 1960's few ophthalmologists had seen a laser lesion. But today, with extensive use of argon laser retinal photocoagulators, almost all ophthalmologists have some degree of familiarity with that type of laser lesion. This at least expands the basis for some degree of proper diagnosis and reduces the chance of a totally incorrect connection of ocular pathology with laser exposure. Again, we return to the problem posed earlier: that the laser-treated eye is not a normal eye. But as laser use expands in ophthalmology, the variety of lasers increases, and less diseased eyes are treated, a general level of understanding should increase in the clinical community.

Dr. Tengroth: I should like to mention a technical paper from RAF Farnborough (U.K.) that Dave Sliney can give the exact reference to. It provided calculations to show that the actual risk probability of direct viewing of a LRF or LD at hazardous levels was extremely small.

Mr. Sliney: I believe you are referring to the British risk studies of exposure outside a laser range as the result of airborne laser equipment malfunction or laser reflections. Certainly, these probability estimates are far smaller than one in a million. Our concern, however, is intentional exposure because of "horseplay" by individuals who do not appreciate the danger or because someone in the target area, who has his protective goggles removed, does not receive word that lasers have been turned on. This is a higher probability by my estimates, but fortunately we have no such reports in the Army as of this date.

Dr. Wolbarsht: I know of three cases where individuals have intentionally directed lasers at other people, and at least one resulted in injury; so this is possible.

Dr. Tengroth: As an ophthalmologist, I am annoyed by people who come into my office claiming they are exposed to laser radiation but cannot tell me from where or from what. I suspect you have similar problems in this country, a psychological problem.

GENERAL DISCUSSION

COL Ranadive: Any questions or comments?

Dr. Zwick: Since the panel is constituted largely of individuals concerned with morphology, I remain uncertain as to what the panel believes should be the correlation between function and retinal pathology. We need some basis for study. If a patient has a lesion--either in the fovea or inside or outside the macula--what kind of change in retinal function would you expect?

Dr. Tengroth: We cannot define the origin of the lesion as laser related.

Dr. Zwick: Well, disregard the etiology. What can you expect?

Dr. Tengroth: Even a laser-induced lesion in the macula, even the foveola, will not change the function.

Dr. Zwick: By function, you mean only acuity?

Dr. Tengroth: Acuity, or green or red electrophysiology. Indeed, electrophysiology can be ruled out anyway because most of that is really meaningless. If the entire foveola is destroyed, resulting in 20/200 vision, you can see an electrophysiological change.

Dr. Zwick: Are you defining damage as 20/200?

Dr. Tengroth: If you want to look at visual acuity, where a moderate lesion exists, you can see a change at 20/30. Color vision is more defined, and one can detect a color sensitivity change even when the acuity is 20/20. The point is that you can still have normal macular function with a small macular lesion present.

Dr. Zwick: If one studies another etiology, another disease not at all related to lasers, and follow the pathology, are we equally in the dark with regard to correlating morphological and functional changes?

Dr. Tengroth: Yes, absolutely.

Dr. Ham: In this regard, it may be interesting if Dr. LaPiana would comment on the study he performed with Dr. Mark Tso a few years ago. Three patients, about to have their eyes enucleated, volunteered to gaze at the sun. As I recall, the morphological changes were severe, but all three patients had normal acuity 4 or 5 hours after the exposure.

COL LaPiana: That is right. These patients had malignant tumors of their eyes which necessitated nucleation, but they had normal foveolae. The point of the study was to determine if soldiers really could stand to look at the sun and induce a burn of the foveola in spite of blepharospasm or tearing. We found out it was very easy for them to do so, even with dilated pupil. So if someone intentionally wanted to burn his or her

fovea, as hundreds of draftees did during the Vietnam War, it is perfectly possible to do so. As Dr. Ham said, despite significant morphological alterations, later confirmed by light microscopy, there was a return to preexposure visual acuity levels within 48 hours after exposure.

COL Tredici: That is Dr. Zwick's question. Can we follow someone functionally regardless of the appearance of the retina? The answer, I think, is yes. If we only test for function and do not become distracted by appearance, and should the vision never deteriorate below 20/20, we should not care what the macula looks like. The only important functional area for the eye is 1 degree. Should we see morphology, and then we test for 10 years and see no visual acuity drop below 20/20 (perhaps I couldn't test to 20/10) we could relax, but one has to draw a line - probably 20/20.

Dr. Tengroth: But, I can tell you that you can have that situation. I saw a case with normal visual acuity after exposure, and the only deficiency noted was her color vision. The visual acuity does not tell everything.

COL Tredici: But, it tells you about 80 percent.

Dr. Tengroth: The patient might have a change in refraction and might become more and more hyperopic. If you do not examine more thoroughly, you could overlook a melanoma or something. Visual acuity is not sufficient if you want to rule out any serious condition. But, I agree with you that if the man is working, forget about it.

COL Tredici: Yes.

Dr. Tengroth: But, it still concerns me if the patient goes to an ophthalmologist who sees a lesion in an eye with 20/20 vision. What is your position then, medically-legally?

Dr. Ham: In our experience from using monkeys trained to perform for visual acuity tests, it took enormous energies to see a change in visual acuity. We had to produce a foveal lesion at 90 J/cm² before the monkey had a visual acuity reduction. We concluded long ago that visual acuity is a very poor indicator of retinal injury. I learned at the outset from Dr. Dupont Guerry (ophthalmologist) that it is amazing how much of the foveal region can be damaged without visual acuity changes.

Dr. Timberlake: Are you sure that the monkeys were using their central foveas in the visual acuity tests.

Mr. Mueller: You can never be sure of that.

Dr. Timberlake: The monkeys may use a broad area of their macula in these tests. These visual acuity measurements may not be very refined.

Dr. Zwick: In our experience, we can test monkeys at a visual acuity better than 20/20, and the only way I know to achieve a visual acuity better than 20/20 is to use the fovea.

Dr. Wolbarsht: Another problem of an examination for suspected lesions is that closely following a patient by taking many fundus photographs, and extensive use of the indirect ophthalmoscope, could cause damage in itself. Seriously, I do not believe we should discount this problem. It is not a negligible risk for close followup.

COL Ranadive: What do we do now? I hear that visual acuity tests are not useful, that fundus exams are not useful, that ophthalmoscopic exams are very difficult. Is there anything left?

COL Tredici: I still think that visual acuity is the test of choice. We cannot disregard it. We have nothing better.

COL Ranadive: To focus this discussion, we should now review my original questions at the outset of this symposium. Those questions related to what examining protocol was necessary for preplacement, periodic and termination examinations as well as to the postaccident followup.

Dr. Wolbarsht: The preplacement examinations will be discussed in panel tomorrow.

Dr. Tengroth: To answer your questions, COL Ranadive, we must first ask about our objectives. Is our only objective a legal one? Are we trying to improve laser safety and preclude hazards? Are we interested in trying to treat laser accident victims? We would provide different answers, depending on the objectives.

COL Ranadive: We have all three objectives.

Dr. Tengroth: From what Ms. Norman told us, I do not think we can really solve the legal problem. I think it is completely ridiculous to argue that such examinations will protect the patient from further laser burns since we have insufficient knowledge of this, and we shall not look at the periphery. Thus, we can set aside this objective. Finally, with regard to an accident followup where a clear laser burn is evident, I think a number of clinical studies are warranted.

I think one of the discussions today suggests the scope of the examinations: a thorough examination with ophthalmoscopy of the central retina plus the normal function tests. Color vision tests are done anyway. For legal purposes, the patient should be told of the existence of a laser lesion. When the patient leaves employment, the examination should be repeated. I do not think every person working with lasers needs a special examination. Doesn't everyone in the Army normally receive a vision test or examination?

COL Whitmore: They are supposed to receive an induction and separation examination.

COL Tredici: Fine. You need only add that if a soldier thinks he has been exposed to a laser, he be seen by an ophthalmologist, not by an optometrist, in this instance.

Mr. Mueller: Does the average soldier receive a funduscopy examination?

COL Whitmore: This is unclear.

Dr. Ham: What type of eye examinations do servicemen receive in the Armed Forces when they depart?

COL Whitmore: To answer this, the location of the examination is paramount. At most Armed Forces Examining and Entrance Stations (AFEES) and induction centers, I would expect a vision test with examination by direct ophthalmoscope, and probably the slit lamp by a physician who may or may not be well trained in this examination. When being separated he receives a visual acuity test and at our institution if he is being "boarded out" for medical reasons the examination includes ophthalmoscopy, if there is a referral.

Dr. Tengroth: With regard to laser workers, I think you should eliminate requirements for periodic examinations (at 1- to 2-year intervals), if they still exist in your country.

Dr. Ham: One conclusion we should reach in this symposium is the scope and extent of the examination for a serviceman leaving the Armed Forces.

COL Tredici: In the recent past, the scope and extent of most medical examinations have decreased. Tests are abbreviated, routine chest x rays are given only on every third visit, etc. But we must incorporate any laser requirements into the general examination protocols. For example, in the Air Force, all 55,000 flyers are examined thoroughly on a yearly basis, and they receive a good visual examination. This population is taken care of. Other enlistees are examined on reenlistment. If our examining medical technicians will carry out the tests with the Armed Forces Vision Tester or Ortho-Rater®, we have a good foundation. Despite criticisms, it is a good screening examination. It includes a superior stereoscopic test with visual acuity in each eye. Thus, if a patient has a laser lesion which impacts on this test, that patient needs to be examined. Remember, if you examine 60 and one falls outside your criteria, you need to really examine only one in 60. We have a good system if we will just use it. Specific laser research staff members at high risk could, nevertheless, receive more than the simple screening test. The more sophisticated tests (i.e., 100-hue, contrast sensitivity) really are seldom necessary. Using the Ortho-Rater with an Amsler grid will eliminate 98 percent of our difficulties.

Do not worry about missing peripheral lesions. Most of us have more peripheral lesions than we are ever likely to receive from a laser and we never know it. It is the central 1-degree field that is important, and a lesion there will be picked up on the Amsler grid.

LASER INJURY TO THE ANTERIOR SEGMENT--ULTRAVIOLET RADIATION

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San Antonio, Texas

I thought it would be appropriate for us to divide the topic into spectral regions: UV and IR. I shall begin with a discussion of UV effects.

At short UV wavelengths, less than 295 nm, there is very little penetration into the cornea and damage is limited largely to the epithelial layer about 50 μ m thick in the primate eye. The damage mechanism is photochemical. Ultraviolet photons are absorbed by specific molecular targets which, while in the excited state, undergo a chemical reaction. The resulting photoinduced products interfere with normal cellular function, and this is expressed, sometimes later, in terms of degeneration or even death of the cell. This cellular damage has an action spectrum (relative sensitivity vs wavelength) which has a minimum radiation exposure at maximum cellular sensitivity, in the 260-280 nm range. What is seen clinically is a corneal haze or clouding which develops after a time delay of several hours. Its time course is similar to that of sunburn. Although the victim may not be aware of the original UV radiation exposure, as the corneal clouding develops, secondary symptoms occur which can be quite painful and debilitating. If the exposed corneal area is extensive enough, there will probably be photophobia, with accompanying conjunctivitis, the sensation of sand in the eyes, and some tearing. This is the result of the breakdown of corneal epithelial cells which are sloughed off into the tear layer. The delay time between exposure and acute symptoms varies between several hours to 1 day, and the discomfort will generally last for a period of about 1 day depending upon the severity of the exposure.

For longer UV wavelengths from 300 nm to 400 nm, there is greater penetration of UV into and through the cornea, and the lens is the primary absorber of near-UV. Lenticular effects are, therefore, seen in this spectral region, and there is a potential for damage to the stroma and endothelial layers of the cornea. In most cases, damage to the lens and corneal stroma will be permanent and, thus, more serious than damage to the corneal epithelium. Injury to the stroma will generally only occur at significantly higher (one order of magnitude) exposures than are necessary to induce injury to the epithelial layer. The damage would be disruption of the normal ordering of stromal fibers, resulting in a scar which would interfere with vision to an extent depending on the size of the lesion. Exposure levels capable of inducing stromal damage are also likely to produce a lenticular opacity. The damage mechanism is thermal and, at sufficiently high laser irradiances, an immediate thermal damage to the absorbing tissue is possible. In the lens, this would normally be anterior surface clouding, and in some cases a very dense opacity. A hazy lenticular lesion may disappear over a period of months, but, in my experience, if the damage appears as a discrete whitish opacity, it is permanent. We have followed some experimental animal subjects for a period of up to several years and saw no changes in this type of laser-induced cataract. This completes my summary of UV effects.

LASER INJURY TO THE ANTERIOR SEGMENT--INFRARED RADIATION

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I shall address IR effects. This morning I showed an action spectrum for visible laser retinal effects. Figure 1 shows the relative thresholds as a function of wavelength for wavelengths from the visible into the IR. The ED₅₀ point at 1.32 μm was obtained very recently using a pulsed Nd:YAG laser. As we traverse the spectrum from 1.3 μm to 2.0 μm , the cornea and anterior ocular media undergo a transition from highly transparent to effectively opaque. The injury threshold dose response curve in this region reflects this transition.

Figure 2 shows an example of a corneal lesion which was produced by the firing of a blank round of ammunition fired at close range - not by a laser. This was kindly loaned to me by COL LaPiana. It nicely illustrates a lesion that should not be mistaken for laser injury, since one can observe the debris imbedded in the cornea. Figure 3 is a photograph of an acute lesion produced by a CO₂ laser (10.6 μm). Because this IR radiation is absorbed in a thin layer (i.e., a small volume of tissue), this volume becomes quite hot, and a thermal lesion results. The epithelium is wrinkled and, in this illustration, because of the high dose, a stromal scar and endothelial effects are also noted.

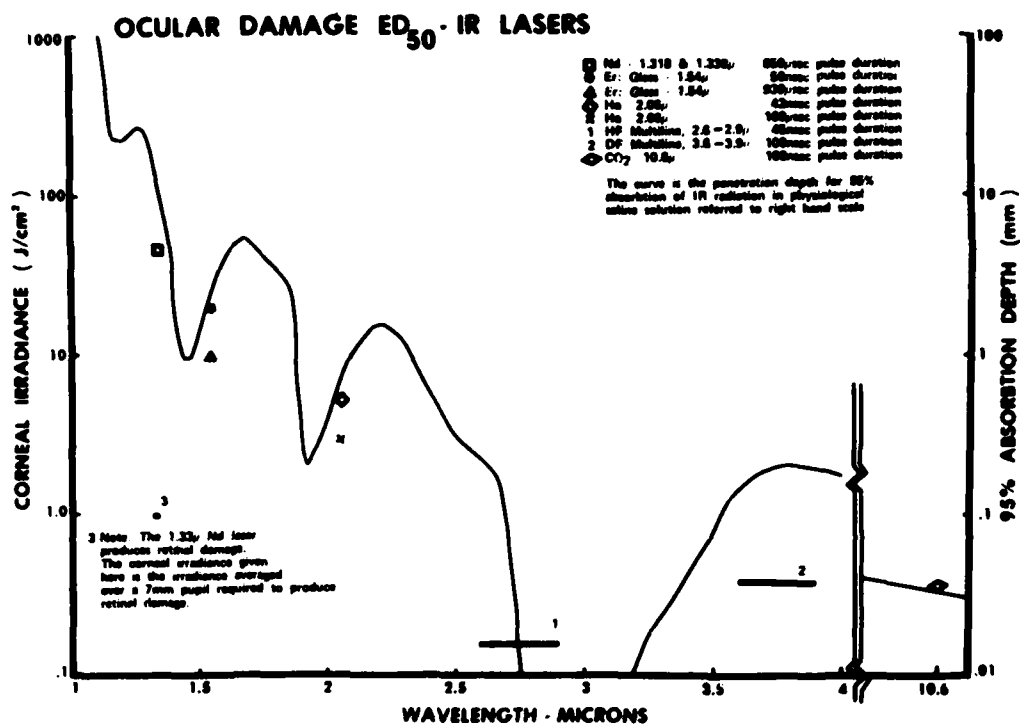


Figure 1 (Stuck). Relative Thresholds as a Function of Wavelength for Wavelengths From the Visible into the IR

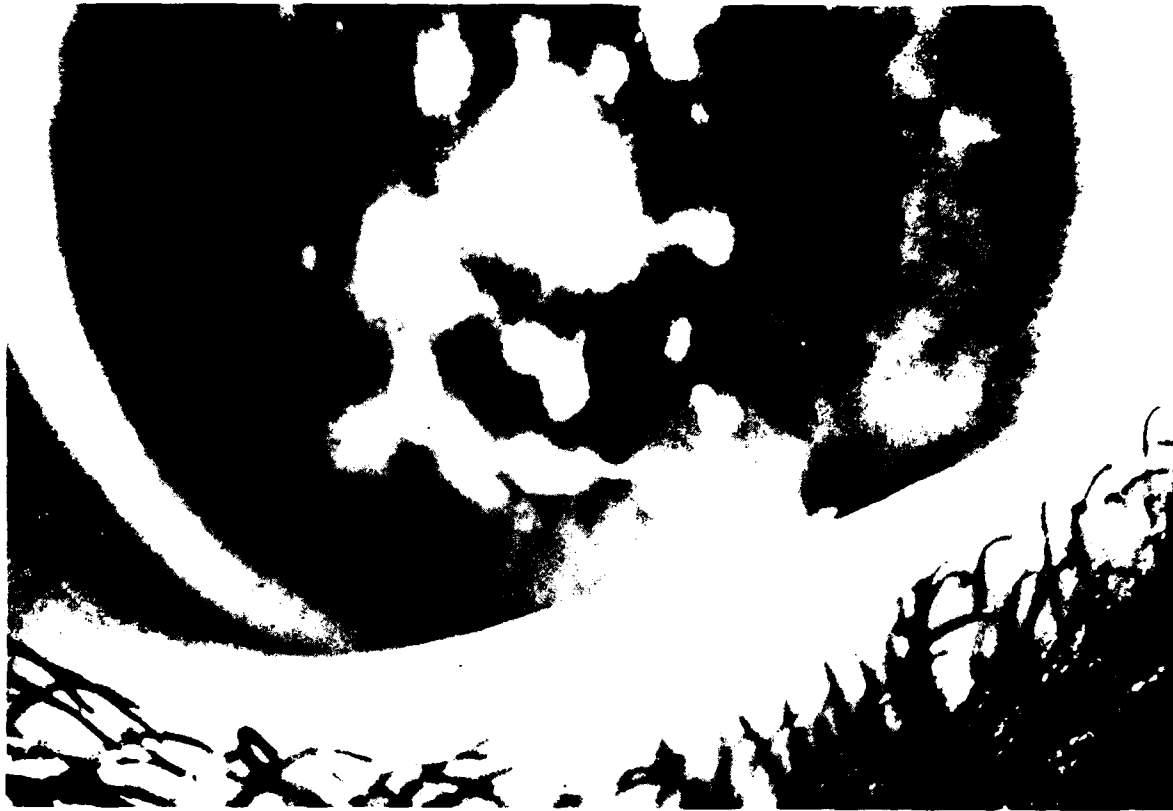


Figure 2 (Stuck). Corneal Lesion Produced by Firing a Blank Round of Ammunition Fired at Close Range

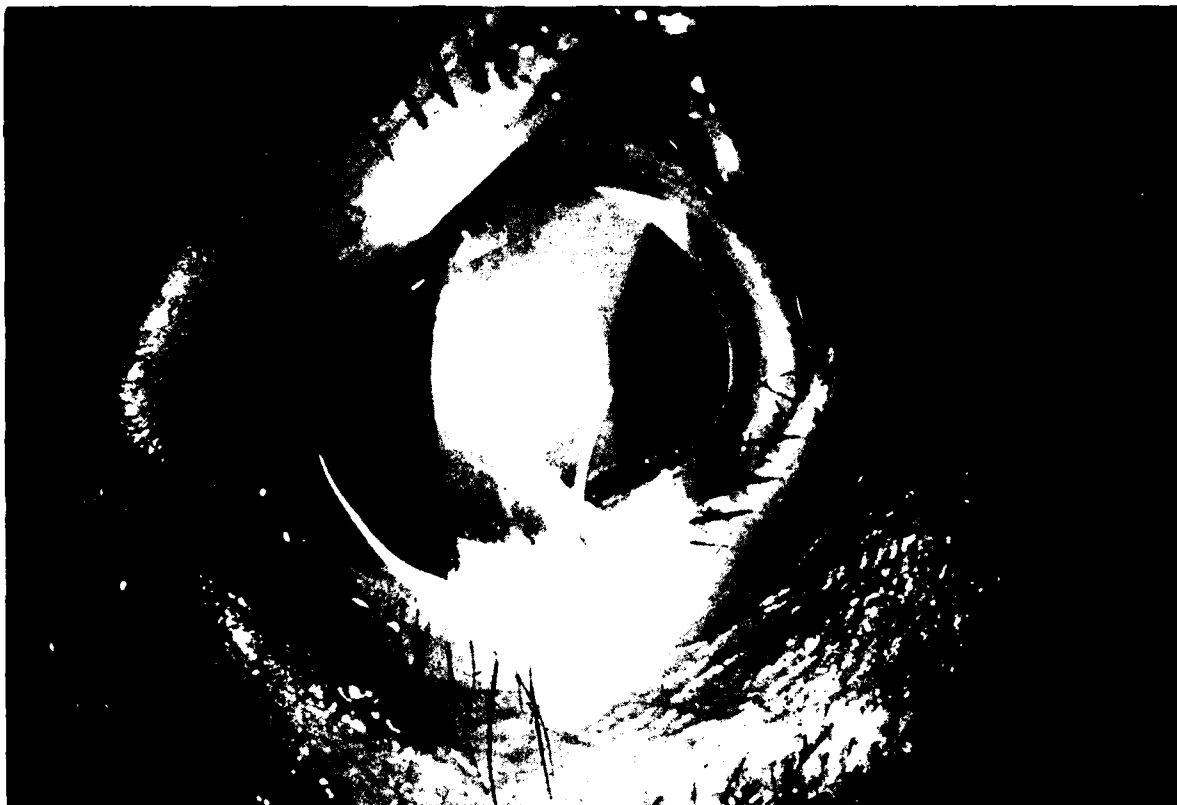


Figure 3 (Stuck). Acute Lesion Produced by a CO₂ Laser

Photographs of a more severe CO₂ laser-induced corneal lesion 1-hour postexposure and then 13 days later show a persistent stromal scar. At 13 days it is greatly diminished from the acute response, indicating that the corneal epithelium undergoes repair and only the stromal scar remains.

Lesions resulting from near-threshold exposure doses involve only the corneal epithelium, because the IR absorption takes place so superficially at 10.6 μm . These lesions are not apparent by slit-lamp examination 48 hours postexposure.

Figure 4 shows a series of nine lesions produced by an erbium (Er) laser operating at 1.54 μm . These lesions are about twice the ED₅₀ exposure dose. Unlike the CO₂ laser lesions, these lesions—even at threshold (ED₅₀)—extended into the stroma as shown by a photograph taken with a biomicroscope (Figure 5).

Figure 6 shows a corneal lesion produced by a holmium (Ho), Q-switched laser operating at 2.06 μm . The exposure doses were varied for the three exposures shown. Even though the beam diameter at the cornea was held constant, one can readily observe that the lesion diameter increased with radiation exposure. At this wavelength, the lesions were not as deep as at 1.54 μm , as would be expected by the reduced IR penetration depth.

As part of the study of 1.54 and 2.06 μm laser injury of the cornea, we repeated subthreshold exposures at doses above the permissible exposure limits, for several times over several days. We observed these corneas over a period of time using slit-lamp biomicroscopy, specular microscopy, and fluorescein staining. We carefully examined the corneal endothelial cell mosaic and cell size. Over a course of time we could not observe a cumulative, delayed, long-term effect.

To summarize: From 1 to 10.6 μm , the ED₅₀ exposure dose for corneal injury varies over orders of magnitude, and the nature of the response also varies.

Our study of the ocular effects at 1.3 μm is most interesting, because there is a crossover from retinal to corneal effects. In the process of repeating exposures, lesions developed on the anterior surface of the lens which only became apparent 3 or 4 days postexposure.

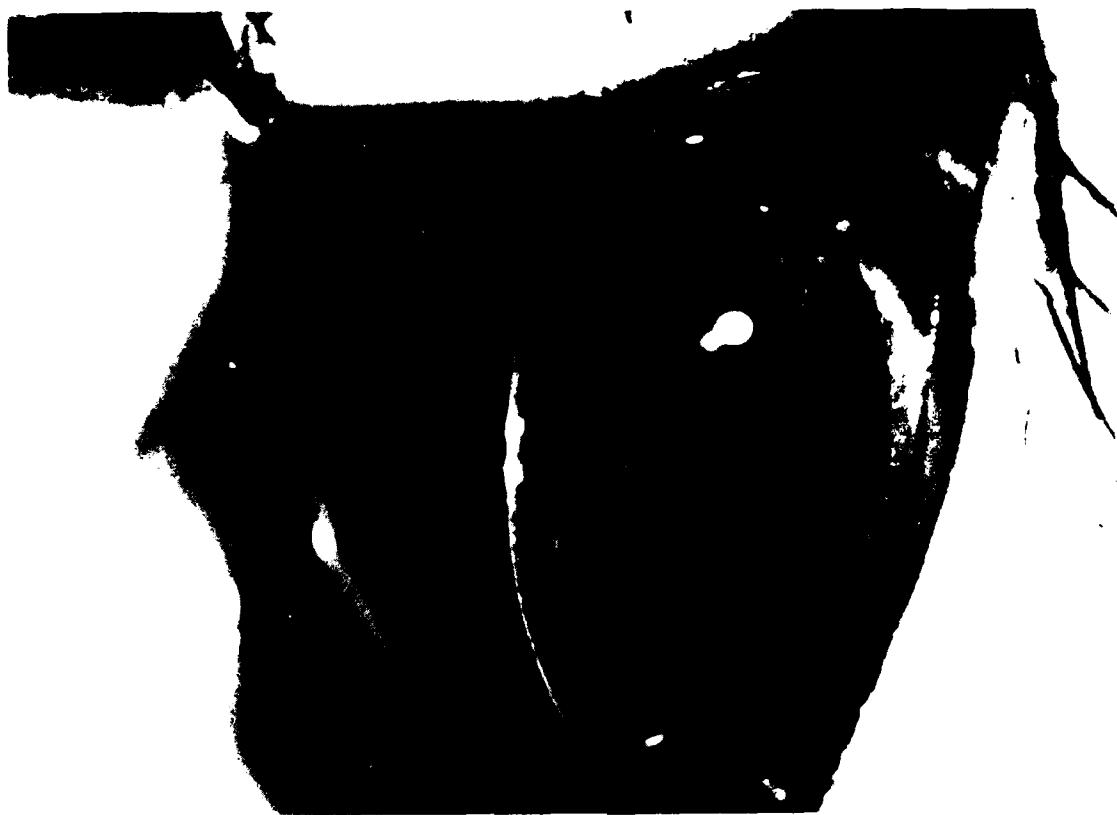


Figure 4 (Stuck). Lesions Produced by an Er Laser Operating at 1.54 μm .

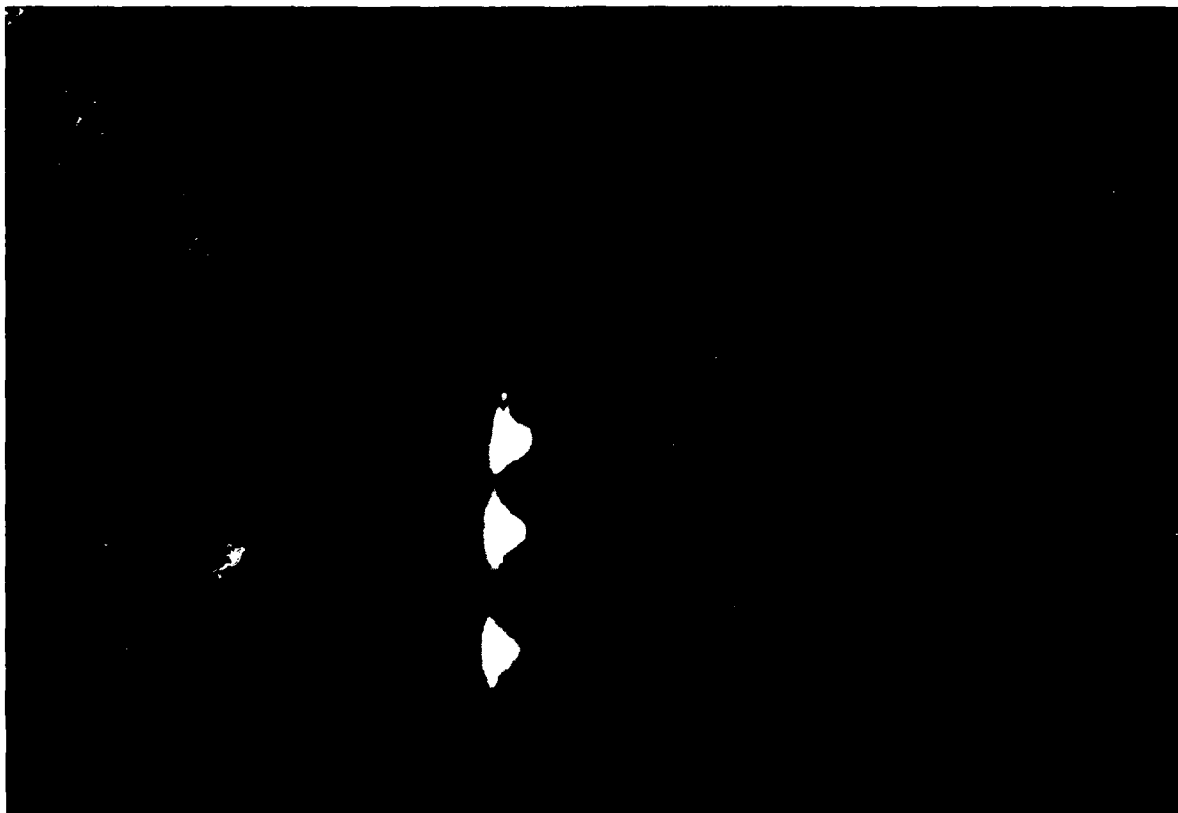


Figure 5 (Stuck). Corneal Laser Lesions Produced by an Er Laser Viewed Through a Biomicroscope. Note the involvement into the Stromal layer.



Figure 6 (Stuck). Corneal Lesions Produced by a Ho, Q-switched Laser
Operating at $2.06\ \mu\text{m}$

LASER INJURY TO THE ANTERIOR SEGMENT--INFRARED CATARACT

Myron L. Wolbarsht, Ph.D.
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I shall add to the remarks of the previous two speakers with regard to effects upon the lens. It now appears that delayed effects upon the lens are possible from both UV radiation and IR. These effects are worthy of consideration if one encounters lengthy or repeated exposures to these spectral bands above those already found in the natural environment. The latter levels are already sufficient to begin to cause lens deterioration and, in some cases, complications in the cornea as well.

There are two conventional theories for the etiology of IR cataract. One theory (Goldmann, 1933) holds that the radiant energy is absorbed in the iris and converted into heat, which is subsequently transferred to the lens leading to a "thermal" cataract. The opposing theory (Vogt, 1912) holds that direct absorption of radiant energy in the lens--despite its relatively low absorption in the visible spectrum and only somewhat greater absorption in the near infrared--led to the cataract. The injury mechanism was generally considered thermal. However, today there is growing evidence which supports a photochemical damage mechanism for IR cataractogenesis (Pitts, et al., 1981; Wolbarsht, 1980). The implication is that, in theory, repeated, subacute threshold exposures could result in the development of a lenticular opacity from exposures lasting over extended periods of time--even years. Such exposures would probably exceed environmental exposure levels. There are many industrial exposures, as in glass blowing, steel puddling, etc., where this occurs and a higher incidence of cataract in these individuals has been reported in the past.

Thus, chronic IR laser exposures should be kept in mind. Realistically, at the present time, from common lasers used for contemplated applications, there is no real likelihood of such chronic exposures. This is only a problem to remember for the future.

With UV laser exposure a different problem arises. Again, referring to exposure levels likely to be encountered in everyday laser usage, there is a delay in onset of signs and symptoms. For example, UV photokeratitis (like sunburn) will not appear until hours after the exposure. This can lead to a difficulty for the victim in connecting his symptoms with the laser exposure. Obviously, I doubt that an ophthalmologist examining a patient who works routinely with a nitrogen laser (337 nm) and who wakes up at night with a burning sensation in his cornea will not relate the symptoms to laser use. But for the patient who develops a cataract and argues that it resulted from working with an Er laser 20 years previously, there could well be controversy. It would be difficult to determine if that IR laser exposure actually predisposed him to cataract in later life. Of course, there are people today who could recognize that lesion and could pin it to the laser exposure; Dr. Zaret's name springs readily to mind. We are ready for questions.

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GENERAL DISCUSSION

COL Tredici: Please clarify what part of the IR is absorbed in the lens that can cause heat cataract. I thought most IR was transmitted to the retina.

Dr. Wolbarsht: This infrared absorption may not be an environmental problem, but in my laboratory we were able to produce cataracts by CW Nd:YAG (1064 nm) exposure of only the lens.

COL Tredici: I can believe that you could get sufficient heat with a YAG laser.

Dr. Wolbarsht: But, we believe this to be a photochemical mechanism of cataractogenesis, since there was reciprocity of exposure time and irradiance (exposure dose rate).

COL Tredici: That which is absorbed beyond 800 nm would produce glass-blower's cataract - one of the first industrial diseases recognized at the time of the industrial revolution.

Dr. Wolbarsht: What is absorbed depends upon the source spectra relative to the lens absorption.

Dr. Ham: The ocular media have an absorption spectrum almost identical to that of water.

Mr. Mueller: The nearest water absorption band is at about 980 nm and the ocular media absorb all beyond 1,400 nm.

Dr. Wolbarsht: The primary (significant) molecule of absorption in the lens is probably not water. It may be a hydrated molecule responsible, but I am convinced that the process is a photochemical effect. It is not a thermal effect; that is, absorption by water and conversion to heat and cooking of certain lens proteins. The effect does seem to involve lens proteins, such that certain proteins become insoluble.

COL Tredici: This takes a long period of time.

Dr. Wolbarsht: Yes, it takes a long time period and the exact mechanism remains unknown.

Dr. Timberlake: Does one ever encounter individuals who have been exposed to high levels of UV or IR radiation, who have visual complaints in the absence of pronounced pain or observable haziness of the cornea?

Dr. Wolbarsht: I think Dr. Tengroth or one of the ophthalmologists might better be able to answer that question, but certainly tearing or blurring of vision would occur before pain would result.

Dr. Tengroth: This is difficult to answer. One might see changes in the small glands of the conjunctiva under high resolution examination. With regard to UV photokeratitis, we know exactly what to look for.

Dr. Timberlake: My question is stimulated by the fact that perceptions are often the most sensitive diagnostic indicators. Hence, I wonder if patients can subjectively detect a subtle visual disturbance before it is possible to see it clinically.

Dr. Wolbarsht: Patients can sometimes detect such problems even when they do not have them.

COL Tredici: I can address this from the UV standpoint from our experiments for National Aeronautics and Space Administration (NASA). Patients can experience some blurring of vision and some swelling of the corneal epithelial cells, but this originates only shortly before they experience pain. From a practical point of view, the pain is much more significant. Their vision is compromised, anyway, by spasm of the lids. Subtle color vision changes also occur, but this is really dwarfed in significance by the pain.

I am skeptical of the UV etiology for cataracts, however. I have read the reports of biochemical studies of UV cataract, but I see little clinical evidence of this. To attain significant UV doses to the lens, you would be significantly sunburned.

Dr. Wolbarsht: I think the link between UV cataracts and brunescence is too strong to argue that UV cataracts do not exist.

COL Tredici: As a clinician, I cannot observe a cataract and relate it to a UV radiation exposure which occurred 4 years previously. What I see clinically is that UV radiation effects occur at the corneal epithelium.

Dr. Wolbarsht: Brunescant cataract results from near-UV radiation.

Dr. Tengroth: We see one patient at a time. We are not computers. If we were, we might be able to accumulate data that patients who visit the tropics more often have a higher cataract incidence. If there were unique characteristics for a UV cataract, then we could diagnose this, but there are not.

Dr. Ham: I have a question for Mr. Stuck. Could you clarify that 1.3 μm was the triple crossover point for corneal, lens, and retinal damage? What were the exposure durations and beam diameters?

Mr. Stuck: By varying beam diameter incident on the cornea, we could select one effect over another since the ratios of relative exposures would vary with this. The pulse duration was of the order of 200 μs when retinal damage was noted. In the CW mode the cornea and lens were more vulnerable. Again, the cornea showed effect within 30 minutes, but the translucent opacity which showed up on the anterior surface of the lens could not be seen until 4 days postexposure. This animal was followed for 6 months, and both the stromal scars and the lens opacities were still apparent.

COL Tredici: Why did you have retinal lesions in one condition and not in the others?

Mr. Stuck: The exposure conditions were different. For the cornea thresholds, we focussed the beam.

Dr. Tengroth: Where were the lenticular changes: capsular, subcapsular, in the epithelial layer?

Mr. Stuck: In the epithelial layer.

Dr. Ham: Dr. Zuclich, could you comment on the thresholds for lenticular opacities from the 325 nm He-Cd lasers?

Dr. Zuclich: I do not have any thresholds at 325 nm for the lens - only for the retina and the cornea.

Mr. Sliney: Dr. Ham, you are thinking of two earlier studies: one was reported by MacKeen, et al., who described lens damage in rabbits [in Ophthal. Res., 1973]. Later, Ebbers and Sears published a study [Am. J. Optom. Physiol. Optics, March 1975]. Both studies showed corneal lesions appearing first, followed by lens damage if exposures of several joules were employed.

Dr. Zuclich: The cornea is more sensitive at 325 nm.

Dr. Ham: In our laboratory, an exposure of 8-9 J/cm² was the threshold for retinal damage in an aphakic monkey.

Mr. Moss: If I may return to the subject of IR cataract--I have a question. From my review of the literature, reports of IR cataract appear only to be reported for very long-term chronic exposure: Can this really be of any significance for military personnel who might be exposed to pulsed sources?

Dr. Wolbarsht: I do not think it is a problem from today's lasers. But remember, new lasers are being developed all the time. We should learn from past experience not to claim that a particular type of laser or a particular spectral band is not of concern or will not cause a certain effect. History continually proves us wrong on this account.

Mr. Stuck: There are Army efforts to develop systems which operate in the 1-2 μ m region. We are looking at holmium (Ho) LRF's (2.06 μ m), an erbium (Er) laser development at 1.732 μ m, and another so-called "eye-safe" Er LRF at 1.54 μ m. Furthermore, other neodymium (Nd) lines at 1.318, 1.338, 1.358 μ m have been explored for LRF use. In terms of occupational exposure limits, the 1.3 μ m lines still fall into the retinal hazard category as if they were as hazardous as the 1.06 Nd line, but of course they are not.

COL Tredici: Wouldn't any exposures from these types of lasers be acute, though?

Mr. Stuck: Yes.

COL Tredici: We have no one in the military, of whom I am aware, who receives the 25-year chronic IR exposure, such as steelpuddlers and glassblowers.

Mr. Stuck: The issue of chronic exposure effects is very difficult to address experimentally. The closest approach we made was the 6-month followup of the IR laser experiment I mentioned earlier; in that instance there were negative findings.

CAPT Blaise: To clarify one point, where did you find the IR laser cataract?

Mr. Stuck: On the anterior surface of the lens.

CAPT Blaise: The reason I ask this question is that we were always taught that glassblower's cataract is a posterior subcapsular or posterior polar cataract. We always argued that this was caused by IR, but your findings suggest that IR causes anterior polar effects. The National Institute for Occupational Safety and Health (NIOSH) sponsored a study in Houston to experimentally duplicate or mimic the classical industrial "heat cataract" and this was unsuccessful. So, I think that we must be leery of the claim that glassblower's cataract is the result of IR exposure.

Dr. Wolbarsht: No. This problem arises because of a delayed time course. In our studies we often saw the lesions develop first on the anterior surface, but after a few days they appeared to have migrated to the posterior of the lens as if they had followed the lens fibers. Hence, if you injure a lens fiber in the front, it may be more visible, after a period of time, in the posterior--in the same fiber, but enlarged and subcapsular.

Dr. Tengroth: There is an obvious reason for this. From a purely optical point of view you would need to see the posterior portion of the eye, and the repair metabolism in the posterior part is much worse than the anterior.

Dr. Wolbarsht: I think this explains why there are so many cataracts reported as posterior subcapsular regardless of where the lesion started.

Mr. Stuck: If one reviews the clinical pictures of the time course, our experimental lesions showed the anterior surface lesions at 15 days and even at 3 months postexposure.

Dr. Tengroth: There is no true IR cataract. The only unique sign of an IR cataract is a true capsular exfoliation. I agree with Dr. Wolbarsht that an IR cataract often appears first as anterior subcapsular and migrates to the posterior portion of the lens, where it remains. There are some signs of anterior subcapsular opacities which appear behind the iris which is also probably an IR induced effect.

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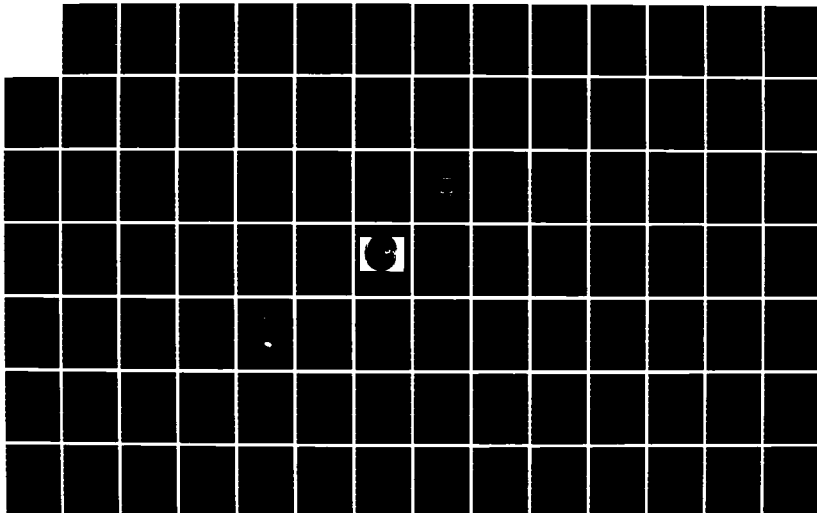
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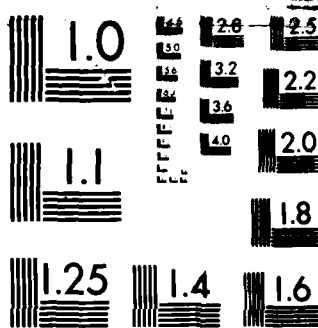
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Mr. Sliney: I think that is worthwhile to remember that in the IR-A and IR-B spectral regions (0.76 - 3.0 μm) the selective absorption of the cornea, lens, iris, and aqueous interchange roles as significant absorbers of optical radiation. This can be seen in Figure 4-25, on page 145, of the Sliney-Wolbarsht book. The point is that we should not be surprised if slightly different etiologies exist with varying IR wavelengths and for different exposure durations where the relative influence of the heat conduction will vary.

CAPT Blaise: It sounds like we are still in the realm of speculation.

Dr. Wolbarsht: This is a good point, but simple absorption and heat production may not be the key. There is still research needed to understand the mechanism, but there are some scientific principles we can follow here. This is not an area open to pure speculation. There are experiments which suggest a photochemical mechanism for cataractogenesis, and these experimental results are not in complete disagreement with the clinical reports.

Mr. Moss: The NIOSH-supported study by Dr. Donald Pitts, at the University of Houston, employed a broadband source which included some visible and, perhaps, even a small amount of UV radiation [Pitts, et al., Arch Klin Ophth, 1981]. However, this discussion, concerned only IR. There may be two different effects, depending upon wavelength. Clearly, there is still much confusion with regard to IR cataract.

Dr. Wolbarsht: It is true, in the NIOSH research report you spoke of, that Dr. Pitts thought that the cataract was a thermal lesion resulting from a transfer of heat to the iris. But look at his data, disregarding his interpretation for a moment; the data show reciprocity between exposure time and irradiance levels. I am unwilling to say that is not a photochemical effect. Remember that our laboratory produced the same results by confining 1,064 nm laser radiation to the lens alone, without any possibility of iris involvement.

Dr. Ham: Thermal lesions of the retina obey reciprocity, too.

Dr. Wolbarsht: Not for lengthy exposures of minutes. Those thermal lesion thresholds are at a constant power, not a constant energy.

Mr. Moss: It is true that the rabbits in Pitts' study were exposed all day long, 8 hours a day.

COL Tredici: Dr. Pitts plans to continue his study. He is borrowing our photocoagulator, but, finally, we must remember that cataract is a generic term.

Dr. Ham: Dr. Wolbarsht, why do you suggest that IR cataracts are photochemical in nature?

Dr. Wolbarsht: Well, just the fact that both our data and Dr. Pitts' data show a reciprocity of time and exposure rate. I find it difficult to believe that the temperature rise of the lens in these experiments was more than 1 degree. The dose could be fractionated over a few different days, could be delivered over a 30-minute period, or could be given in a fraction of a second to achieve the same threshold. I find it hard to say that this change can result from a thermal effect.

Dr. Tengroth: I am not quite sure that one can say that a thermal mechanism is ruled out. There are many complex factors leading to a cataract, and heat-stress effects might add to this.

Dr. Wolbarsht: That is perfectly true. There is a thermal cataract. One can direct a laser beam at the iris, and immediately behind the iris a damaged area of the lens appears on the interior surface, which then spreads into a cataract. There are two effects, and the particular exposure conditions will govern which is predominant. But, the irradiances necessary to produce these thermal stresses are quite high. Indeed, the exposed person would be very uncomfortably aware of the exposure if, indeed, he could live through a whole-body irradiation at such a level.

COL Ranadive: At this late hour, we must adjourn for dinner at Marticks' Restaurant in Baltimore.

LIMITATIONS OF OPHTHALMIC EXAMINATIONS/DIAGNOSES AND MEDICAL MANPOWER

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My remarks today shall be very brief. We have been asked to discuss the problems in examination and diagnosis and provide some reference to available manpower. The elegant presentations yesterday by Drs. Wolfe and Tengroth clearly illuminated for the entire group--especially the nonophthalmologists--the incredible difficulty inherent in simply labeling a fundus lesion. I would like to reiterate that, in the present state of our knowledge as clinicians, there is no observation we can use, in an isolated sense, which would permit us to say a specific lesion happened from a specific insult, e.g., that a lesion occurred 20 years ago from a laser. This brings up some pathologic information and some principles relating to the pathologic remodeling of lesions which I shall refer to Dr. LaPiana for discussion at the completion of my remarks. He shall present one of the principles that we would like to put forth.

First, I would like to review the laser medical surveillance protocol we follow at Walter Reed Army Medical Center (WRAMC), and then I shall review our ophthalmologic manpower in the Army. Following this, LTC Pitts shall present the optometric manpower situation.

Our current laser medical surveillance guidance, as implemented at WRAMC, is based on AR 40-46. We are basically presented with a list of patients from various agencies, e.g., the Federal Bureau of Investigation (FBI), Harry Diamond Laboratories, etc. These patients are included in our regular schedule and are given full patient appointments. Occasionally, we believe we are not performing a screening examination but are administering a near complete ophthalmologic examination. The full, basic examination includes the best corrected visual acuity, an intraocular pressure test, because we are doing funduscopy under dilated pupils. The one major element that we are not performing at this time is visual field testing. If the patient has no pathologic change in his macular area or in the fundus in general, the description will simply state so in the record. If there is an observable lesion, we document it verbally in the record; if the lesion is of an unusual or suspicious nature, we would document it photographically for our own purpose. We are not photographing every individual, nor are we documenting a parafoveal aggregate of pigment or focal area of depigmentation. We are the beneficiaries of this conference. We need guidance as to how to proceed as well.

Eight US Army medical centers (MEDCEN's) have ophthalmologists. Five of the MEDCEN's have teaching programs. This illustrates one of our problems: the distribution of available locations of care and the location of persons using lasers. One problem we must ultimately discuss is how to

get patients to these areas to examine them. It brings up, in my mind at least, the concept of some sort of screening process going on in the outlying areas, followed by referral of suspicious lesions to central areas, such as the MEDCEN's. This is something we will have to discuss further this afternoon. We do not have residents at all eight MEDCEN's. There are 18 residents at the five MEDCEN's where we have resident staffing. The US Army community hospitals are augmented by three civilian ophthalmologists. Outside Continental United States, there are 14 ophthalmologists, and there is the one research position at LAIR. Perhaps that represents John Wolfe. We were expecting an Army ophthalmologist there this summer, but he went into civilian practice. The ophthalmologists and the optometrists at the various US Army community hospitals may appear to be numerous, and it would seem that a tremendous manpower base exists to handle laser eye examinations. But, there is a large variation in the level of experience and expertise. Luckily, a third of our manpower consists of residents in training. Also, the staffs of these MEDCEN's, although both certified and advanced in their experience, have a subspecialty. For example, some concentrate on corneal diseases; others, like myself, concentrate on retinal diseases. There is, inevitably, a variation in the level of expertise to deal specifically with one problem, such as the observation of a retinal lesion. This becomes another problem which we shall have to address in our overall concept. Therefore, some form of standardization of the ultimate examination of individuals suspected to have been exposed to laser radiation must occur. This triggers in my mind the concept of a central registry or area to funnel these patients.

QUESTION: COL Ranadive: Can I first ask a question? We recently had an exercise to define 52 to 73 divisional manpower spaces. What are the needs for ophthalmologists in the Army Medical Department if the needs are defined already?

ANSWER: COL Whitmore: As the needs are currently defined, we are slightly ahead of our proper rate. In other words, we have been told to reduce our residency input this year from 12 to 10. This is problematic and another reason why I am interested in what we decide here.

OPTOMETRIC MANPOWER

LTC Walter G. Pitts, MSC
Occupational and Environmental Medicine Division
US Army Environmental Hygiene Agency
Aberdeen Proving Ground, Maryland

I am presenting the information on Army optometrists for COL Giroux, since he was unable to attend. There are approximately 214 optometrists in the Army. It is likely that this is the maximum authorization for anytime in the near future. They are located in over 82 posts. By comparison, Mr. Sliney and I estimate that, at present, most lasers are concentrated at only about 12 posts. At these 12 posts, three of the clinics are one-man clinics (i.e., one optometrist in the clinic), two are three-man clinics, three are five-man clinics, three are six-man clinics, and one is a seven-man clinic.

As part of the Army's Occupational Vision Program, personnel of this Agency make periodic visits to local preventive medicine services and review the local medical surveillance program for ionizing and nonionizing radiation workers. In this regard, I review many medical records to determine what examinations have or have not been performed. This review reveals two categories of examination programs. One finds both well documented examinations and instances of very minimal information located in the medical records. The documentation appears to depend upon how the patients were scheduled. At a post with a smaller concentration of lasers, primarily with laboratory workers, patients are scheduled on a routine basis and are given full appointments. By contrast, at installations such as Fort Irwin and Fort Hunter Liggett, California, where large field exercises or field tests take place, patients will be brought in by the "busload". At Fort Irwin, there was a request to screen 900 within days of notification. The screening examinations were actually performed, as I recall, in 2 to 2 1/2 days. One can imagine the detail of medical recording in such a situation. Medical records in such a program might have entries such as "pigmented areas" and nothing more, or as detailed as "pigmented area, superior to macula." Such descriptions will not provide much information if referred to at a later date. Certainly all the clinicians here know that even your own writing in a medical record, reviewed a year later, can be difficult to interpret unless you include extensive drawings/photographs or extremely detailed descriptions of what was seen.

To summarize, medical records may contain so little information in the surveillance examination as to be almost useless. Later, I shall present my own view of the surveillance program in the Army.

DISCUSSION

COL Whitmore: Your conclusion is that the problems arise with requirements to screen large numbers of mainly enlisted personnel. There is no problem when the three scientists require an examination.

LTC Pitts: That is correct.

LTC Tredici: The Army does not have a program as in the Air Force where all enlistees pass through the Air Force Training Center at Lackland Air Force Base for their initial basic training.

LTC Pitts: Only laser maintenance personnel, who undergo training at the Army Ordnance School at Aberdeen Proving Ground, are enlistees given preplacement laser eye examinations.

COL Tredici: At Lackland Air Force Base the enlistees are examined in a "production line." New tests can be incorporated into this program. For example, we are conducting a research project where 10,000 enlistees a month are examined before they go through 10-weeks of basic training. Afterward, they go to different bases. Once they are spread over many bases, there is no easy method to conduct a general examination program.

LTC Pitts: This underscores our problem. Generally, these field tests will draw participants from a number of different posts. If they are all from one post, it might be possible to perform examinations before the test. All too often, though, hundreds show up and all are in a TDY status. Hence, no one wants to wait 3 weeks for these examinations to be accomplished on a sound basis.

COL Tredici: Laser training is not a separate activity, but concomitant with other activities.

LTC Pitts: Most examinations have been for large-scale operational testing of developmental equipment, not for basic training. To summarize the optometry situation, the problems center on one-man clinics where a sudden examination requirement can overload the clinician. The seven-man clinic can normally absorb special requirements.

Mr. Moss: Can the Army, like the Public Health Service, bring in contract physicians to help when the need arises?

LTC Pitts: Yes, this can be done for long-term programs, but is difficult on a one-time basis. This is not usually done and it is quite expensive.

COL Ranadive: In terms of contract services, Congress recently provided budgetary authority to the Department of the Army to obtain more contract physicians because of the present shortage of Medical Corps officers. But, when one considers the difficulty of obtaining the needed specialties among contract surgeons, and the indications that this program will be reduced,

the picture is gloomy. Alternatively, patients can be sent to civilian treatment centers on a case-by-case basis, but this is cumbersome. I do not feel that either approach will help much to solve our problem.

COL Whitmore: Our current situation at WRAMC has been manageable because we have been asked to examine only a limited group of people. Considering the size of the clinic, we could not manage the influx of a large group of basically healthy people into a facility that is really tasked to treat and to manage illness. The size of the problem could become really overwhelming in that regard.

There are two other concepts that I would like to address. The first one is the problem of diagnosis, and why it is difficult for us to make that diagnosis. COL Frank LaPiana, from WRAMC, will give some background in aspects of pathology in that regard.

The second concept relates to long-term effects of laser exposure to which I alluded yesterday. I recommend that our position be that we are uncertain, but the potential for long-term effects does exist because of the great significance of any damage to Bruch's membrane at various laser energy levels. But monitoring every single patient indefinitely on an annual basis would not be a cost-effective method to manage these patients. However, this might be handled by a central registry which would identify and track exposed individuals so that we could call them back and examine them periodically. This would allow us not only to have control over that patient population but to be able to observe them over a long period of time and actually develop some of the needed natural history data for lesions of this type.

OPHTHALMIC SURVEILLANCE CONSIDERATIONS

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I have a few comments which are made to support a few recommendations. The first comment is that if you visit this area follow Dave Sliney's advice about where to eat and follow Dr. Ham's advice about which wine to have with your dinner.

A couple of comments originate from listening to the discussions yesterday; the first concerns basic science. One of my former teachers frequently emphasized that the retina has a very limited repertoire of responses to trauma. Some of us stated this yesterday. The retina can only respond to any of a variety of injurious stimuli in a limited fashion. This is true of other forms of trauma--blunt or otherwise--and the spectrum of responses ranges from total destruction of the neural elements to destruction which can be repaired. Even though the retina is part of the central nervous system and central nervous system cells are not supposedly capable of repair (at least neurons), the outer segments of the photoreceptors fortunately can be regenerated. This has been shown beautifully by Mark Tso and others (1973) at the AFIP. They showed that laser lesions of a certain intensity destroy the photoreceptor outer segments; disrupt the underlying retinal pigment epithelium, but with time, the retinal pigment epithelium is reconstituted, and the photoreceptor outer segments are regenerated. The retinal pigment epithelium does not always regenerate with a normal composition or concentration of pigment granules. This may explain why one can see a restoration of function and yet a persisting morphological change, as in solar maculopathy.

With regard to another matter entirely, I believe that any active-duty military or civilian patient, who has a foveolar lesion will obtain the medical care that he or she needs. Our society is keyed to high-quality visual functioning, and this is particularly true in the military. I do not think we need to worry about missing patients in times of peace or war who have a significant foveolar lesion from a laser, or from anything else. Those patients will be admitted into the system. And I do not believe that one should worry about surveillance to either detect and thereby obtain the opportunity to study or, hopefully, to care for those patients. The corollary to this is that any patient who has even the serious possibility of a laser lesion should be referred to a medical center that has a retinal specialist. The medical center should be equipped with the sophisticated psychophysical and fluorescein angiographic devices necessary to conduct scientifically valid and purposeful studies. Fortunately, the three ophthalmologic consultants to the three uniformed services' Surgeon Generals are all retinal specialists at this time. We, therefore, have a tremendous opportunity to develop a method to begin to study these patients who may be injured in the future. Over time, this may provide answers to some of the essential questions for which we have no answers at present.

To that end I think we should definitely have a triservice registry. Before I heard of the existence of such a registry at USAEHA, I was planning to suggest that it be under the aegis of our Uniformed Services University, of the Health Sciences, in Bethesda. I think that remains a viable possibility, but I think we need to develop a program analogous exactly to what the AFIP does with its registry, whether it takes the form of a central repository of good, solid clinical information or has a format for calling patients back for long-term studies.

Another issue which was raised yesterday concerned treatment. Dr. Whitmore and I were talking about this after dinner last night. We concluded that there should have been someone here from the Veterans Administration. After all, it is the Veterans Administration that is chartered to provide care for service-connected disability. The large percentage of Americans who have served in the military usually did not have a full 20-year career. If we are worried about the treatment of the long-term complications of lasers induced in times of peace or war, then certainly the Veterans Administration must be involved. They have ophthalmologists; they also have optometrists.

This is strictly parenthetical aside from the development of laser protection, but I worry that, in a battlefield of the future, the first GI who stands up and yells, "Oh, my God, I've been lased and I can't see" will generate the same effect that occurred as the first GI who was gassed in World War I. There could be massive departure from the trenches. This we must address and I know that Dave Sliney, COL Beatrice, and many others are working to develop laser protection for our soldiers. This is a critical area which needs devoted time and effort.

REFERENCE

Tso, M. O. M., Photic Maculopathy in Rhesus Monkey. A Light and Electron Microscopy Study, Invest Ophth, 12(1): 17-34 (January 1973)

DISCUSSION

COL Ranadive: The concerns of both of you and your recognition of the need for joint cooperation within the Armed Services are particularly informative. A military ophthalmologist needs to know about laser effects on the eye. What are your present and future plans as teachers?

COL Whitmore: This underscores the fundamental problem that exists with the present limited manpower situation. That is, to provide either a system which delivers patients to the point where that expertise lies or disseminating an educational program that will lead to the necessary expertise to recognize and classify those lesions. We have a tremendous problem in education.

COL Ranadive: We have to try to find a group of service ophthalmologists who are interested in developing a program. I am glad to see that you recognize the problem, and I am sure you will meet the challenge.

COL LaPiana: I do not think there will be a great difficulty in finding service ophthalmologists who will be interested in studying patients who have suffered a laser injury. I think, however, that it will be impossible to find sufficient numbers to survey the entire Army.

COL Ranadive: I was referring to your point of the future battlefield with lasers as a threat to the GI and the obvious role of the military ophthalmologist. The recognition of laser injury by all ophthalmologists on active duty in the Army Medical Department is absolutely essential. That does not mean that everyone needs to be a retinal specialist.

OCCUPATIONAL VISION PROGRAMS AND RECORDKEEPING

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Historically, the responsibility for the Army's Occupational Vision Program has been located here at USAEHA. There are three optometrists assigned to the Occupational Vision Team. Any ocular surveillance program is part of an installation's occupational vision program, which is the responsibility of the preventive medicine activity.

Laser surveillance examinations are not new. The Army initiated a laser surveillance program in the 1960's, and it is continued today. In the early 1970's there was an emphasis on microwave surveillance, and a laser-microwave ocular effects team was established. Although "laser" was in the title of this team, most of the team's work centered on the surveillance of microwave/radar workers. The team was initiated by Dr. Bud Appleton, who was the consultant for ophthalmology to The Surgeon General at that time. The team was to have consisted of an ophthalmologist, an optometrist and one technician. As occurs in the Army, it was easy to recruit the ophthalmologist and the optometrist, but a technician could not be obtained; so it began with an optometrist and an ophthalmologist. Later, it consisted of two optometrists. The team visited a number of posts and examined a selected group of workers on a 12- to 18-month cycle. It performed approximately 8,000 surveillance examinations, based upon my review of their records and reports. The examinations consisted of visual acuity, funduscopy, and slit-lamp biomicroscopy with dilated pupils. The results were recorded on a special form. Dr. Appleton evaluated the accumulated data and came to the conclusion that no changes could be detected in microwave/radar workers. Therefore, the examinations were no longer considered necessary for microwave workers (Hathaway, et al., 1977). This special surveillance program was discontinued in 1976.

Ocular surveillance of lasers workers, was also initiated in the early 1960's. Of course, there existed very few lasers at that time. The TB MED 279 was issued, which required all laser workers to receive an eye exam. The next edition of TB MED 279 was issued in 1975 and required only personnel working in research, development, testing, and evaluation (RDTE) or in laser maintenance activities to have examinations. Surveillance (after 1975) was to be performed on an individual basis with no organized Army-wide effort. It also required examinations for users of equipment determined by The Surgeon General to have a significant risk of exposure (currently, there are no fielded systems in this category). The first category (RDTE personnel) becomes large only when it is interpreted to apply to large field tests. For example, at Fort Hunter Liggett, 900 people were sent to the Optometry Clinic for laser surveillance examinations. As I explained earlier, the soldiers were on TDY and could not wait for weeks to be worked into the normal schedule. Therefore, a mass examination was scheduled. A lot of pathology was found during the

examinations and was referred to the Ophthalmology Clinic. This overtaxed the Optometry Clinic with examinations and the Ophthalmology Clinic with referrals. Most optometry clinics are booked with patient loads at least 2 to 3 weeks ahead, some up to 8 weeks ahead; so it is very difficult to interrupt a schedule for 2 to 3 days to perform surveillance examinations.

Laser maintenance personnel are another group requiring laser surveillance examinations. Currently, laser maintenance personnel are trained at the Ordnance School, APG, and are seen by USAEHA optometrists for their preassignment eye examination.

When visiting different posts to perform occupational vision surveys, I review the medical records, especially the civilian medical records located in the occupational health clinics and look at the scope of the laser surveillance examinations. I found that very often the preassignment examination had been completed and was adequate, but I seldom found copies of termination examinations.

QUESTION: COL Ranadive: Do they retain the records of employees who terminated work a long time ago?

ANSWER: LTC Pitts: Yes, there is a requirement to retain the medical records for a specified number of years.

QUESTION: COL Whitmore: When is a termination examination performed? when one ceases working with a laser?

ANSWER: LTC Pitts: It should be at the termination of work with a laser system. However, most occupational health nurses reported that they could not remember having sent anyone for a termination examination. A worker could have had a termination examination and still be working for the Government.

QUESTION: COL LaPiana: Is it not true that the regulations require merely that a civilian be offered the opportunity of having a termination examination? Perhaps many of them simply refuse to undergo one.

ANSWER: LTC Pitts: You are correct that it is voluntary, but, frankly, I do not think this termination examination is even offered.

COMMENT: Dr. Parr: I must say it was not offered to me, and I worked with lasers for many years at Fort Knox some time ago.

QUESTION: LTC Pitts: Did you have a preplacement examination?

ANSWER: Dr. Parr: No; but we did have the periodic ophthalmoscopic surveillance on a yearly basis.

LTC Pitts (continues): Today we require yearly surveillance, but this examination is just a vision screening examination employing something like an Armed Forces Vision Tester or commercial vision screener. The main purpose of this periodic examination is to check central visual acuity and maintain contact between the occupational health staff and the worker. During this yearly visit, the staff person will talk with the laser worker about his eye protection. This is the same test performed on workers in all (including chemical and impact) eye hazardous areas.

Immediately after an accidental exposure or suspected exposure of the eye to a hazardous laser, an examination should be performed. I believe that we have had good results at USAEHA. We have had few laser incidents, although a few false alarms have occurred. So far there have been two incidents where individuals have been suspected of having a laser-induced lesion. One occurred at Fort Hunter Liggett, California, and the other occurred at Yuma Proving Ground, Arizona. One was a false alarm. The other is still being debated as to whether it should be placed in the confirmed or the suspected category. Most authorities feel that it should be placed in the suspected category.

In the past there has been a question as to who should perform the laser surveillance examinations. In AR 40-46 and TB MED 279 it states that these exams should be performed by optometrists, ophthalmologists, and physicians skilled in funduscopy and biomicroscopy of the eye. The purpose for the last statement was to include ophthalmology residents. At most posts, the system works in the following way: A patient is referred to the Optometry Clinic. If the optometrist sees anything which he or she thinks should be referred or has any questions, the patient is referred to the ophthalmologist. At some posts, the patient may go directly to the Ophthalmology Service. This varies depending upon location. The problem frequently encountered is that no ophthalmologist is located at the post. Therefore, the optometrist will see the patient and, if necessary, refer the patient to either a local civilian ophthalmologist for evaluation or the nearest major Army medical treatment facility where an ophthalmologist is available. The examining ophthalmologist may not necessarily be a retinal specialist. The lack of knowledge about lasers was a problem in the two recent incidents of alleged retinal injury. There is a lack of optometrists and ophthalmologists who know anything about Army laser systems. If a soldier walks into a clinic and states that he is working with a G/VLLD, this term means nothing to the optometrist or ophthalmologist. Not only do they not know that it is a laser or what type laser is in it, they have no idea what the piece of equipment is used for. Thus, we believe that laser information must be better disseminated. We have made an effort in the optometry field by presenting 2 hours of instruction at the Optometric Management Conference last May. At one of the larger optometry conference meetings next week in Denver, we shall present a 6-hour block of instruction. Dr. Beatrice, from LAIR, will give a 90-minute presentation. Dr. Gibbons, from the Air Force (USAFSAM), will give a 90-minute presentation. Mr. Franks, from USAEHA, will give a 60-minute presentation on laser equipment and where it is located. I shall give a 30- to 45-minute presentation on reporting procedures for a suspected injury.

The requirements of a surveillance examination, as outlined in TB MED 279, are visual acuity, funduscopy and biomicroscopy. If visual acuity is below 20/40, a pinhole test is given. In large unit screening efforts, visual acuity may be all that is measured. There maybe no effort to measure the best corrected visual acuity. If the individual has forgotten his spectacles, the uncorrected visual acuity is recorded (e.g., 20-60; although his corrected vision may be 20-20). The examinations performed in the clinics with a normal full-appointment period usually provide the patient's corrected visual acuity; the pupil is dilated and the fundus examined. The detail in the record varies with as little as a two-word explanation, such as "depigmented areas," or as much as a half a page with drawings. The detail of the record seems to depend upon the time factor. By contrast, in the high-volume screenings, the patient is dilated for the funduscopy, but no slit-lamp examination is performed. Most of the records of the regular examinations have very limited drawings and very few photographs.

Reference

Hathaway, J. A., N. Stern, E. M. Soles, and E. Leighton, Ocular Medical Suveillance on Microwave and Laser Workers, J Occ Med, 19(10): 683-688 (1977).

DISCUSSION

COL Rosenberg: How technically difficult is it to obtain photographs? Yesterday, I heard a comment that it is difficult, and I believe that. However, in terms of having something in the record, it might be useful.

LTC Pitts: It is an art, but I believe that even a fairly poor photograph is probably much more superior than a fair drawing. I do not know if that opinion is generally held. Does anyone wish to comment?

COL Tredici: We train technicians with 2-3 hours of lectures and then a half morning of photography practice. They will probably then photograph with good results as much as 98 percent of the time. Their photographs sometimes show a little fringe at the edge because the optics are not centered, but the disc and the macula are in every photograph 98 or 99 percent of the time.

COL Rosenberg: How much time does this take?

COL Tredici: About 3 minutes.

LTC Pitts: Dilating the eye takes more time, but the subjects are already dilated anyway.

COL Tredici: One major problem is the cost of the fundus camera.

LTC Pitts: Later, matching the photographs with the record is quite a problem.

Dr. Zwick: I understand that many people have imperfections like drusen (small white areas), normally. Is drusen documented in some way?

LTC Pitts: I have seen little mention of it in examination records.

Mr. Zwick: Can one differentiate drusen from a laser lesion?

COL Tredici: Drusen does not interfere with vision in any way.

Mr. Mueller: Do you have diagram outlines of the left and right fundus on your final examination paper, so that it would be easy for the examiner to write down a lesion?

LTC Pitts: No; most of the time the description is written on a form with only lines (Form 600).

Mr. Mueller: If an outline of the fundus were on the form, the examiner could know to record something, and you should have greater success in obtaining better records.

LTC Pitts: Yes. We have been tasked to write a technical guide for the optometrist and the ophthalmologist. In my opinion such a standardized form is needed. It should have a place to record "biomicroscope findings," with schematic drawings of the lens laterally, anteriorly, and posteriorly to permit the examiner to place a dot where an opacity is located. This would also force the examiner to use the biomicroscope.

COL Rosenberg: Since new forms are approved all the time, I cannot see why a form with a figure of the eyeball on it could not be authorized.

LTC Pitts: This form should have one section for the preassignment examination and a second section for the termination examination on the same page, so that the two examinations are not separated. In evaluating the preassignment and termination examinations at Fort Hunter Liggett, we encountered difficulties in obtaining examination records on all the involved personnel even though there was a time lapse of only a few months. We could not determine for certain if each soldier had both examinations. A standard form with both preassignment and termination examinations on the same page would make this task less difficult.

COL Whitmore: Someone asked how difficult it was to take a fundus photograph, and whether it would be better to have a poor fundus photograph than no description. I think that one of the problems in establishing rather dogmatic guidelines relates to the matter of clinical judgment. For example, if a large toxoplasmosis is present in the macula, even an out-of-focus photograph would certainly be better than no description, but if there is only a subtle, localized area of drusen in the fovea, an out-of-focus photograph might not show it. In this instance, a description would be needed. A photograph cannot be a substitute for clinical judgment.

COL Rosenberg: We are not trying to eliminate one or the other. What is sought is to provide some clinical descriptions with a photograph that might shed some light to someone examining it 5 years later.

LTC Pitts: Yes. I wonder at times if a good form could eliminate some problems at outlying clinics where no ophthalmologist is available. If an individual in a routine examination is found to have a lesion, a fundus photograph could be sent to the ophthalmologist to whom the optometrist refers. A consultation by phone should result in the individual being evaluated only when really needed and would reduce patient travel.

Dr. Zwick: I still think that it is important to have some type of documentation, regardless of the expertise of the examiner, because the type of threshold laser lesion about which you are worried could easily be mistaken for drusen--or vice versa.

Dr. Wolbarsht: The important finding is whether a functional change takes place. If a functional change occurs, it is important to document why it occurred. It is really not worthwhile looking at the fundus unless one can show a functional change. It might be better to develop some functional

tests for subtle changes that can be given to everyone. If a functional change took place during a field test, as demonstrated by a change in pretest and posttest results, one should examine the fundus and perhaps identify the cause; e.g., perhaps it was related to the laser.

LTC Pitts: I agree that the most important aspect to the individual is function.

Dr. Wolbarsht: Even from the liability standpoint, a functional change is the important factor.

COL Whitmore: From the standpoints of the individual, from epidemiology or preventive medicine, I think that any lesion is important. If the Army is causing nonfunctional, unphysiological changing lesions, the very fact that such lesions result from a field test is important. For example, there were several patients who concerned us at Fort Hunter Liggett. If we have a systematic error in our safety out there, and laser eye injuries are resulting in the field, we need to know about it so we can correct it.

COL Ranadive: Your point is well taken. I do not know if you heard yesterday's discussion. Before it, I was under the same impression, and I would have said the same thing, with equal conviction, as you have stated this morning--but I was educated yesterday by Dr. Tengroth and other ophthalmologists. The problem is not in terms of the presence of any lesion. The problem is in terms of stating whether any lesion results from laser exposure.

With regard to the statement of Dr. Wolbarsht, I agree with the concept that function is of primary importance in terms of monitoring and determining what has happened, but I believe that we have identified - particularly for the Army Medical Department (irrespective of whether we are talking about laser radiation effects upon the retina) - the need for better documentation of the findings of any particular type of examination. This I submit to you for your consideration.

Dr. Wolbarsht: At this point two problems have been identified in this discussion: one is the liability aspect; and the second relates to whether epidemiological studies can demonstrate, by evaluating people who work with lasers, whether there are adequate safety procedures being practiced. With all due respect for the need to monitor safety practices, I cannot believe that we can now muster the money and the manpower to perform an epidemiological study. The goal would not be concerned only with the functional laser lesions in the macular but also laser lesions throughout the retina. Laser lesions in the periphery would be the most common, but are the exact ones which cannot be found by examination. Therefore, we cannot perform that type of epidemiological study.

COL Ranadive: I fully agree with you on that point.

Dr. Tengroth: I also agree, and it is worthwhile to ask: Why do we have any surveillance at all? I think these examinations are still performed, not for epidemiologic research, but only because of the liability problems we have. With regard to changes, function must be tested. Yesterday we decided that it is more or less impossible for any ophthalmologist to rule out a laser injury by an ophthalmoscopic picture, unless we have a clear-cut story to distinguish a laser lesion from an ordinary scar. As long as we have not ruled this out, the ophthalmoscopic examination is of no value. We have to look at the function, and the functional test could easily be performed by a nonophthalmologist. However, if something is wrong with the macular function, or a serious hazardous exposure is suspected, of course a full ophthalmologic examination is warranted, including intraocular pressure (IOP) and other measures - otherwise we cross the boundary of malpractice. But the pretest and posttest could be visual function examinations exclusively.

LTC Pitts: You mentioned the difficulty of trying to connect an observed lesion in time with an alleged incident of exposure. At Fort Hunter Liggett, this was extremely difficult in at least one incident, when we listened to the story from the individual with the lesion. At first, the story sounded very good. But when we tried to trace the facts of this story, serious doubts developed, because we had two different stories. We could not verify that the individual was ever in the area where he had claimed to be either when we interviewed the individuals who were in charge of the vehicle or when we examined the records of the testing. Yet, the individual claimed that he was there.

Dr. Tengroth: When you encounter an individual who claims a laser injury such as this, you must resort to fundusoscopic examinations, there is no doubt about that. But for routine medical surveillance, functional tests should suffice. Of course, we must decide what kind of functional tests should be used. That is what I think we should discuss here.

LTC Pitts: The validity of the functional tests performed during the Armed Forces entrance examination that everyone receives with some type of screening instrument, I would venture to say, is extremely poor.

COL LaPiana: The quality of the functional testing that is done in the entrance examination is not even matched by the quality of the fundusoscopic examination, which is worthless.

COL Ranadive: Functional testing will be discussed in detail late today. Now I have a few questions. COL Whitmore, you mentioned the number of patients visiting Walter Reed. For what reason are they referred for replacement examination?

COL Whitmore: This was the surveillance of personnel from two agencies: the FBI and HDL.

CAPT Blaise: Is this surveillance of individuals working with hazardous substances or the standard physical examination that is required for the agents' physical fitness?

COL Whitmore: This was only for those using lasers. You see, I am a little confused, I do not know the FBI requirements. The HDL civilian employees should not be referred annually for an examination at Walter Reed Army Medical Center. Something is wrong! We have not had HDL employees in the past few years but we examined a group from the FBI, who, specifically, were tested because they were working with lasers.

Mr. Stuck: Is an annual examination still required for laser workers?

LTC Pitts: The current annual requirement is for vision screening. This does not include funduscopy or slit-lamp biomicroscopy. This comes under the Occupational Vision Program.

COL Whitmore: We had a great deal of resistance from the laser workers examined because we wanted to do more than what they thought we should be doing. We did not understand the limitations discussed here. We did turn up problems not related to laser exposure, such as elevations in intraocular pressure. We really did receive an incredible amount of resistance from the patients themselves and I now understand why. The resistance originated because we were doing more than what was expected.

Mr. Sliney: I would like to point out there was a small company being organized in England to specialize in contract eye examinations of laser workers. Their main selling point was a van with an IR fundus camera that did not require a patient to receive mydriatic drugs. Using an IR focusing system, the person's pupil would dilate in the dark, and then the photograph would be taken. The big selling point to industry was that the worker was not incapacitated all afternoon because his eyes had been dilated.

COL Ranadive: This is a new type of fundus photography.

Dr. Wolbarsht: This IR technique is better than using mydriatics to dilate the pupil. This is ex-stone age ophthalmology.

COL Ranadive: There is one point which I would like to make which may appear to be a side issue to this symposium. I would like to argue for the concept of teaching the principles of occupational medicine to physicians practicing medicine in the Army. Throughout the history of the Army Occupational Health and Occupational Medicine Programs have been applied to Army civilian employees working in the US Army Materiel Development and Readiness Command installations or industrial plants. We have never graduated to the next step, but the same principles can be applied to the practice of medicine by Army physicians upon soldiers. When all of us went to medical school, we were taught that one of the questions that physicians ought to ask a patient is: "What is your occupation?" Military physicians

do this very well. They ask: "What is your occupation?" "Soldier," is the reply and that is where they stop. I believe that it is the responsibility of every teaching clinical chief in the MEDDAC--and I will venture to say, perhaps, in all the three services--to try to encourage our residents to continue that line of questioning just a little bit further. There is more to soldiering than just firing a rifle. I receive all the records of individuals who have been processed through physical disability boards. The case histories, in terms of occupational exposure, are very poor. The physician clearly has a poor concept of each particular soldier's job requirements and "exposures," which may be reflected in terms of assignment limitations. This is a real problem of military medicine. We in the preventive medicine community could help clinicians with this problem. The USAEHA, as you know, is very successful in preparing documents. A document could list those items of military equipment, such as specific lasers, which present hazards to the soldier. Simple, one-word descriptions of the hazard and the possible injuries of each item of equipment would be provided.

COL Whitmore: This is precisely why we performed complete examinations on those patients referred for preassignment or termination examinations. We did not know what type of lasers they were using. Sometimes the patients could not identify the types of lasers.

THE US NAVY EXPERIENCE IN OPHTHALMIC SURVEILLANCE

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First, I shall add one new laser incident to the list of cases presented yesterday. At the Naval Research Laboratory an individual was working with a Class 4 Nd:YAG, pumped-dye, laser system. The individual was unaware of any faults in the system, but suddenly became aware of a scotoma in his right eye. He did not remember being exposed, seeing any bright light, or any symptom or event that he could correlate with the sudden occurrence of a scotoma. He was examined by the ophthalmology department at one of the better universities in Washington. He was diagnosed as having a subhyaloid preretinal hemorrhage and nothing else. Since the patient worked with a Q-switched, Class 4 laser, it was concluded that it was a laser injury. I hope that the preretinal hemorrhage will clear, and I can examine the retina to determine if there is a laser lesion present. This is another case where, once again, there are big questions as to the etiology. Reconstruction of a potential exposure is very complicated. The laser system was composed of several units, and the initial beam went through several step-changes in power and wavelength. The final output of the laser did not appear to be sufficient to cause a Class 4 laser lesion or a hemorrhage - in this case a marked, preretinal hemorrhage. This illustrates the difficulty of diagnosing a laser lesion the occurrence of which cannot be correlated with an exposure incident.

QUESTION: COL Whitmore: What was the patient's age?

ANSWER: CAPT Blaise: In his forties.

QUESTION: COL Whitmore: I wonder if he was in the age group for posterior vitreous detachment?

ANSWER: CAPT Blaise: I do not know.

CAPT Blaise (continues): Returning to the general subject of surveillance examinations, the Navy has had an extensive surveillance program for ionizing radiation workers. Ionizing radiation represents a major problem with submarines and the entire fleet. The Navy has detailed requirements and a strong program in this area; a standard form is available which must be filled out completely. For example, the slit-lamp examination must be recorded in frontal and cross-sectional views of the lens. The examiner must draw in exactly where the lesions are located. However, the educational requirements are still inadequate. A submarine was recently delayed when 25 sailors examined by a Navy ophthalmologist were all disqualified. The incident created a problem in the front office. This resident, as others who have been trained within the Navy, received good training in surgical principles but not in occupational ophthalmology. In my opinion, this problem is not unique to the military residency programs.

With regard to manpower, the Navy currently has approximately 110 optometrists and 59 ophthalmologists. The ophthalmologists are located in naval regional medical centers and some of the larger hospitals. The optometrists are also located at naval regional medical centers and hospitals, but, in addition, some are located in shipyards and areas of high risk. Contract optometrists are also employed within some shipyards.

With regard to the use of lasers, the Marine Corps has some of the same types of LD's and LRF's now in the Army. We have fewer lasers aboard ships.

The ophthalmologists here have heard this before, but I wish to emphasize the need for triservice coordination on the matter of standardized surveillance examinations. It is extremely difficult to justify why a Marine and an Army soldier using the same laser instrument should have different examinations. One surveillance should suffice for a hazard specific examination system.

The Navy utilizes the ANSI Z136.1-1980 Standard, Safe Use of Lasers, at the present time; however, it has been authorized by ANSI to reprint specific sections of ANSI Z136.1 in its instruction on medical surveillance which is being drafted. The Navy's laser/hazard control program is based upon first classifying the hazard of the laser based upon its operating characteristics. The hazard classification is the same for training purposes as for combat. Safety training of the individual is paramount. I just returned from a 2-week visit to England to talk to the British on the medical problems they encountered (especially on the hospital ship) in the Falkland Islands Crisis. From this experience, it became evident that there exists the need for realistic training. To train one way and encounter something else in combat is a severe problem. If live lasers which cause eye injuries are to be encountered, we must protect personnel. Although preventive medicine personnel have focused attention on this problem, progress is needed. The level of safety training of the individual users, other environmental personal factors and, lastly, assignment of qualified personnel as laser safety officers (LSO's) are all very important.

Hazard evaluation is based upon three aspects which, in turn, influence the control measures: (1) the system's capability of injuring an individual, (2) the environment in which the laser is being utilized (e.g., the battlefield, treating patients in the operating room), and (3) the personnel who use or may be exposed to the laser radiation. The hazard classification answers item (1), the relative hazard. Controls vary for each classification and are based upon the primary beam's ability to cause biological damage. Class 1 lasers are considered to be incapable of producing hazardous radiation levels and are exempt from any control measures or medical surveillance requirements.

The Class 2 laser may be viewed directly under controlled exposure conditions and must have a cautionary label affixed to its external surface. The Class 3 laser requires control measures to prevent viewing the direct beam. The Class 4 laser requires the use of controls which prevent exposure of the eye and the skin to the direct and difusing or reflective beam. This represents a stepwise progression of the severity of retinal lesions that could result from direct beam exposure. The Table matches the control measure and medical surveillance with the hazard classification.

TABLE (Blaise). STEP PROGRESSION OF THE SEVERITY OF RETINAL LESIONS

Class	Control Measures*	Medical Surveillance
1	Not applicable	Not applicable
2	Applicable	Not applicable
3	Applicable	Applicable
4	Applicable	Applicable

*In normal operation only. Alignment and maintenance procedures of an enclosed Class 2, 3, 4 laser shall require programs appropriate to the unenclosed laser classification.

The general principle applied to medical surveillance here is to render examinations to those individuals with a known risk of exposure to hazardous radiation and examine only those structures at risk. One problem arises in this approach for the occasional "incidental" visitor to a laser laboratory. A secretary walking through a laser room does not require as detailed a laser examination as the individual "laser worker" with a Class 4 experimental laser. This is very important.

The ANSI Z136.1 standard divides personnel into two categories as assigned by the LSO: "incidental" and "laser personnel." Laser personnel work routinely in a laser environment, whereas incidental personnel are those whose work makes it possible, but unlikely, that they will be exposed to laser energy sufficient to injure their eyes or skin (i.e., custodial, clerical and supervisory personnel not actually working with the laser). Detailed ophthalmic examinations are not required for incidental personnel, only a VA screening test. The manpower requirements are significantly different between the two types of examinations. Therefore, it is important to be specific about the assignment of the term "laser personnel." Examinations are required prior to entry into laser work and following actual or suspected laser injury. Routine periodic examinations are not required. Previously, the ANSI Z-136.1-1976 standard required periodic examinations.

The preassignment examination for laser workers includes best-corrected VA and establishes a baseline against which future damage can be measured and to identify workers who might be at increased risk from chronic exposure. Any existing ocular defect, such as hyperpigmentation or drusen, should be adequately documented to prevent that defect from being later mistaken for a laser lesion and to aid in the diagnosis of the lesion.

The deletion of the periodic examination requirements was based upon the general consensus that there were no chronic health problems related to working with lasers. Injuries are either acute or nonexistent.

Termination examinations are not required by ANSI, but we shall make that requirement mandatory within the Navy and the Marine Corps. This duplicates the termination examination that we have for our nonionizing radiation program. I concur that the AFEES VA examination should not be considered as adequate. The good prework examination should consist of a good case history, VA, and a specific protocol based upon the laser to which the personnel may be exposed. Examinations may be extended further as a health benefit. Although the preplacement examination may become a part of a general examination to include fitting for glasses, etc., in the health service program, the examiner should be an ophthalmologist, optometrist, or other qualified physician, such as our flight surgeon, who has extensive ophthalmic training with which to identify any problems in this screening. The initial examiners may not be able to come up with a definitive diagnosis of a specific problem, but at least they should be able to identify a normal macula and optic nerve and report what is not normal. I fully support the idea that we need to teach occupational medicine personnel what is a normal eye. In the future we shall have a group of military physicians trained at the Uniformed Services University of Health Sciences who will know something about ophthalmology because of its recent emphasis there.

The medical examination and the dermatological examination depend, as mentioned before, on which laser wavelengths are to be encountered. The examination should include any history of photosensitizing drugs, best corrected VA with refraction if less than 20/20, and a thorough evaluation of the structures at risk.

Aphakic persons should receive a complete fundus examination. Examinations of the fundus are not required at preplacement but are required when injury is suspected or when using UV sensitizer agents.

The Amsler grid is not required in the current ANSI standard, although it could be part of a good ophthalmic examination. Fundus photography is not required, but may be useful if a lesion is present and one wishes to identify it for the record.

To summarize, the preplacement and termination examinations of Navy laser workers are wavelength specific with examination of only those ocular structures at risk. Thus, a 25-minute detailed examination is not necessarily required and manpower is minimized. Referrals of suspected or known laser injuries have to be reported to the Bureau of Medicine (BUMED) within 30 days after the incident and the examination must be performed as soon as possible thereafter. A Polaroid® color photograph of the posterior pole, including the macula and the optic nerve, should be taken for known or suspected retinal injuries. Slit-lamp photography is needed when a corneal or lens change is seen. I feel this documentation is extremely important, and it will be kept by the Navy in a repository at BUMED. We support an approach to maintain this information on a triservice basis. If we simply evaluate the cases available today, we shall find that we have a 20-year followup with evidence, or lack thereof, of delayed complications. Are these from a laser? I do not think anybody here can answer that. One is a laser burn, and the other from sungazing. If we are to adequately diagnose an injury, we must have documented a careful case history with the type of laser and exposure conditions set forth. The preentry evaluation must also be available. I think the ANSI Z136 program has a lot of merit. Although a few weak areas exist, it should be supported.

Reference

American National Standards Institute, The Safe Use of Lasers, Proposed Standard Z-136.1, ANSI, New York (1980).

DISCUSSION

COL Whitmore: In which category would you feel that our field soldiers operating lasers should qualify: laser workers or incidental.

CAPT Blaise: It depends on what the laser hazard is.

Mr. Sliney: The ANSI Z-136 standard was really developed for industrial and laboratory situations. Most Army lasers are Class 4 devices. Designators would be Class 3 if single-shot, but fall into Class 4 because they are repetitively pulsed. This fact does not have a large impact on the decision about eye examinations. It does impact upon the interpretation of procedural safety rules in the field. This concerned the United States Air Force so much that they chose to alter the ANSI classifications very slightly by renaming the classes, A, B, C, D and adding a Class E, so that LD's fall into Class C (equivalent to ANSI Class 3) rather than the higher category. The Army does not require eye examinations for ordinary operators of LRF's and LD's for several reasons. There are a large number of operators and, since they are normally protected by filters during the operation of their own device, they are protected more than anyone in the field. It is the test person down range in the field and maintenance personnel who are really at risk. The Army requires examinations for at least the maintenance and RDTE personnel. Examinations for all combat soldiers appear to be impractical. We consider this present approach to be consonant with the ANSI standard since the laser safety officer decides who is at risk. In the Army system, our group is "the laser safety officer" for guidance purposes. It is almost impossible for the operator of the laser to get injured by his own laser beam unless he fires it directly at a retro-reflector at close range, or he does not look through his sight.

COL Whitmore: This is analogous to the ophthalmologist treating a patient with an argon photocoagulator. He is protected by a filter in his eyepiece, but bystanders are at risk.

MAJ Mathewson: We have heard a lot about the extreme difficulty in identifying ordinary lesions produced by a variety of pathologies and whether a lesion may or may not be produced by a laser. We have the same reporting problem in the Army system where a suspected laser injury is not reported for a week or 10 days. It is apparent that any laser injury should be examined within 1 to, perhaps, 3 days to verify its time course. Based on that, would you reconsider the way the services respond to these alleged injuries, to more surely identify the time course of that injury during the first week or 10 days?

CAPT Blaise: I think it is critical that these patients be seen by an ophthalmologist on an emergency basis, rather than held for a routine appointment.

COL Tredici: Referring to the laser injury case presented by CAPT Blaise, I will agree with everything that has been said, but I do not care what is

the etiology of these preexisting lesions. What I need is a fundus photograph taken when a patient enters the service. With this approach, funduscopy is not required for preplacement and termination examinations if technicians can perform good photography. The technician would just compare the two at separation. Even at termination, the determination of the etiology of a lesion is not essential, but I would want the entrance examination photograph taken when the lad came in 3 years ago. If he had absolutely nothing, we know it developed during his enlistment. After today's session, I have changed my mind somewhat about photography. I was the one who took photography out of the entire system in the Air Force because people would buy a camera just to have one even if they only had one laser worker on the base. I have since realized that a \$10,000 camera is cheaper than any physician or even a technician.

COMMENTS: Mr. Sliney: I would like to read into the record the written presentations of Drs. Brennan and Marshall from the United Kingdom.

OPHTHALMIC EXAMINATION OF LASER WORKERS AND INVESTIGATION OF LASER ACCIDENTS

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Abstract: Though ocular surveillance of laser workers is indicated for medical-legal considerations, the clinical aspects are equally important. These include assessment of personnel with pre-existing ocular pathology procedures. Such surveillance is costly, and it is important to restrict screening to workers involved with lasers capable of causing ocular damage.

Differential Diagnosis. The appearances of a laser burn may closely mimic a variety of normally occurring ocular pathologies. The list of diseases which may offer confusion with laser-induced eye damage is legion and includes any condition which can cause areas of blanching, edema or pigment-clumping. A few examples will be cited. A retinal burn can resemble a focal choroiditis, a central serous retinopathy, an eclipse burn or a macular dystrophy. Lens damage can result in cataracts, which may closely simulate those arising congenitally from trauma or in senility. Burns of the iris can resemble a melanoma, while a corneal burn in its later stages may produce a nebula, which may be indistinguishable from those arising from ulceration or dystrophy.

Examination Protocol. It is important to ensure that the examination protocol for workers at risk from hazardous lasers is both relevant and realistic. Given the diversity of wavelengths at which lasers can emit, all ocular tissues are potentially at risk.

The output of lasers which operate in the near UV and the IR-C is absorbed by skin, conjunctiva and cornea. If a worker is solely involved with lasers emitting in these regions, it is only necessary to examine the ocular adnexa and external surfaces of the globe with a loupe; particular attention being paid to a corneal examination using a slit-lamp. The slit-lamp comprises a low power microscope with a light source which is capable of producing an optical knife section. It is possible to focus at different depths and, thereby, examine in detail the transparent media and iris. The slit-lamp techniques of retro reflection and specular reflection may also aid in demonstrating minimal damage which might otherwise remain undiscovered.

The examination scheme suggested for workers who are involved with lasers, which may lead to intraocular as well as damage to the external surfaces, is necessarily more detailed. However, all examinations should be reduced to the minimum, and all hazardous or unpleasant procedures deleted where possible.

It is unlikely that a laser burn would increase intraocular pressure, so tonometry need not be included unless indicated. Similarly, scleral indentation and examinations with a mirror contact lens, and other examinations to visualize the retinal periphery, are disliked and of doubtful value. Field examinations are time-consuming and as scotomata produced by lasers are likely to be large and obvious or small (of around 10-30 microns) and difficult to detect, campimetry and perimetry have not been included as a routine. It has also been suggested that tests of ocular muscle balance should be undertaken, but, again, it is most unlikely that lasers could cause any alteration in tropias or phorias, and the value of such tests is doubtful.

The examination form shown on the next two pages attempts to assess the worker hazard in terms of both lasers used and the worker's particular duties. There follows an inquiry into the worker's ocular and general medical history, particular attention being paid to entoptic phenomena such as the development of afterimages, blind spots and alterations in vision of both form and color. The objective part of the examination is concerned with the external appearance of the eye and adnexa, together with tests of pupillary function. This is followed by mydriasis, which, although inconvenient, is considered necessary and a slit-lamp examination of the cornea, iris and lens; and lastly, an ophthalmoscopic examination of the fundus, with particular attention being devoted to the appearance of the posterior pole. Any pathology is documented, preferable photographically, and in the normal eye a fundus photograph of the posterior pole, including the optic disc and macula, is considered desirable. Any further objective tests are left to the discretion of the examiner based on his findings and opinions.

The subjective examination comprises tests of central and paracentral function, as it is burns of the macula affecting central function which would cause a significant disability. These include tests of VA for near and far, with a refraction where necessary. Color vision is tested using the pseudoisochromatic plates, or an approved lantern subtending a visual angle of 1-3 degrees, as it is possible that colored lasers might selectively damage one type of color receptor when below burn threshold. Paracentral function is tested by means of the Amsler charts. The Amsler grid in its simplest form consists of a black card printed with a white grid pattern. This is held 30 cm from the subject's eye. The subject fixates a spot in the center of the grid, and, at 30 cm, the whole grid subtends a visual angle of approximately 10 degrees around the fixation point. Each eye is tested in turn, and the subject is asked six standard questions.

Question 1 - Do you see the white spot in the center of the squared chart?

This question detects the presence of an absolute or relative central scotoma. If the subject only saw the fixation point when he looked off center, it would reveal the presence of a foveal burn. This would be a severe disability.

OPHTHALMIC SUPERVISION OF LASER WORKERS

Examination dateDate of starting/ending laser work

Name Age

Address

Place of work

Laser Type *	Maximum Output	Class	Special Features
Worker Hazard Rating	High	Medium	Low
	Delete above where applicable		

Ocular history

.....

.....

.....

Entoptic phenomena

.....

.....

Relevant general medical history

.....

.....

		Tick where applicable			
		Right		Left	
		Normal	Abnormal	Normal	Abnormal
<u>External Appearance:</u>					
1. Lids		.....	.....	.....	.....
2. Conjunctiva		.....	.....	.....	.....
3. Cornea		.....	.....	.....	.....
4. Sclera		.....	.....	.....	.....
5. Iris		.....	.....	.....	.....
6. Pupillary size		.....	.....	.....	.....
7. Pupillary reactions		.....	.....	.....	.....
		Far	Near	Far	Near
8. Visual acuity unaided		.....	.....	.....	.....
9. Visual acuity with correction		.....	.....	.....	.....
Correction prescription		.....		.....
Refraction if V.A. achievable less than 6/6 6/6		=6/		=6/	
		Normal	Abnormal	Normal	Abnormal
10. Amsler grid		.....	.....	.....	.....
<u>Colour Vision:</u>					
11. Lantern (1-3 minutes visual angle) and/or		.....	.....	.....	.....
12. Pseudo isochromatic plates					
		Accepted		Refused	
13. Mydriasis					

	Right		Left			
	Normal	Abnormal	Normal	Abnormal		
<u>Slit Lamp:</u>						
14. Cornea	.....	.....	.....	.....
15. Iris	.....	.....	.....	.....
16. Lens	.....	.....	.....	.....
17. Fundus						
18. Fundus photograph of posterior pole	Taken	Not Taken	Taken	Not Taken		
19. Ocular pigmentation	High	Med	Low	High	Med	Low
Additional examinations at discretion of examiner, e.g.						
20. Central fields						
21. Applanation tonometry						
22.						
23.						
24.						

Narrative description of any abnormalities discovered, accompanied by photographs or drawings where applicable.

Examiner's Name

Signature

* Workers who are restricted to the use of lasers operating solely in the infra red wavelengths, above 2 um e.g. carbon dioxide lasers, may have their examinations limited to the ocular adnexa and cornea.

Question 2 - Keeping the gaze fixed upon the white spot in the center, can you see the four corners of the big square? Can you also see the four sides of the square? In other words, can you see the white of the square?

This question does not have a great relevance in laser screening but could detect a scotoma coming in from the side such as the arcuate scotoma of chronic glaucoma, which might offer confusion.

Question 3 - While keeping the gaze fixed always on the central fixation point, do you see the whole square network intact? Or, are there interruptions in the network of squared, like holes or spots? Is it blurred in any place? And if so, where?

These questions reveal the presence of a paracentral scotoma absolute or relative anywhere, except the fovea, within the area of retina tested. It is the question of greatest value in laser screening.

Questions 4 and 5 - Always keeping the gaze fixed on the white spot in the center, do you see all the lines, both horizontal and vertical, quite straight and parallel? In other words, is every small square equal in size and perfectly regular?

Always fixing the gaze upon the center point, independently of blurred spots and distortions, can you see anything else? A movement of certain lines? a vibration or wavering? anything shining? a color of tint? and if so, where on the square?

These questions reveal the presence of metamorphopsia and entoptic phenomena, such as might be produced by small degrees of retinal edema from heat or selective cone destruction by a colored laser causing damage restricted to the photochemical level.

Question 6 - Keeping the central point fixed, at what distance from this point do you place the blur or distortion you see? How many small intact squares do you find between the blur or distortion and the central point that you are keeping your gaze upon?

This question accurately locates damage in relation to the fovea.

Great importance has been attached to the Amsler test, as it is considered to be of great diagnostic value and rapid in use.

Fluorescein Angiography. Fluorescein angiography has proved to be a reliable and sensitive technique for the detection of laser damage to the retina. In animal studies using the rhesus monkey, it has proved to be about six times more sensitive than ophthalmoscopy in the determination of the 50-percent probability of damage to the Q-switched neodymium laser (Borland, et al., 1978).

In man, 3 cubic centimeters (cc) of sodium fluorescein in a 20-25-percent solution are given by rapid intravenous injection, and serial photography is commenced as soon as fluorescein illuminates the fundus and continued at appropriate intervals for up to 10 minutes thereafter. The equipment in use at Farnborough comprises a Zeiss (West) fundus camera with a Baird Atomic B5 exciting filter and an Ilford 109 Delta chromatic 3 barrier filter in the motorized magazine. These filters allow only about 1-percent transmittance in the overlap zone of 480-500 nm. The film used is Ilford FP4, which is developed in Kodak D76.

The background fluorescence varies with phases of the vascular cycle. The first fluorescence seen is the choroidal flush, when the dye first reaches the choroid. This fluorescence is patchy and irregular in distribution. It is followed by the arterial phase, when the fluorescence assumes a fine granular pattern due to the dye in the choriocapillaris being viewed through discontinuities in the pigment epithelium. Fluorescence becomes maximal during the early venous phase and then commences to fade away, assuming once more a granular pattern which becomes coarser with the passage of time. It is during the later venous phase that fluorescent laser lesions are most readily seen.

The ophthalmoscopic appearance of fluorescent lesions depends on whether they have been produced by a near-threshold or suprathreshold exposure. Threshold lesions fluoresce uniformly during the venous phase, but lesions above threshold appear as a ring pattern during the early venous phase and infills slowly from the periphery toward center during the late venous phase. Large fluorescent areas, in excess of 75 microns, are easily seen when superimposed on the background granularity, but small lesions of less than 75 microns are more difficult to see, as they can be more easily confused with background grain.

In lesions at threshold levels, the junction between adjacent pigment epithelial cells, which are called zonular occludens, becomes separated due to thermal damage. This opening represents a break in the chorioretinal barrier and permits free diffusion throughout the irradiated area, and the lesion fluoresces uniformly. In lesions at above-threshold level, the pigment epithelium becomes coagulated and, thus, impermeable to fluorescein except at its periphery. At the periphery, the coagulated shrunken central plaque pulls open the junctions between normal and coagulated cells giving rise, initially, to the typical ring pattern. The ring slowly infills from the periphery to the center with the passage of time.

Accident Procedure. In the event of a suspected laser accident, the workers should be examined using the same protocol as detailed in the proposed form. This examination should be conducted as soon as possible after the event, preferably by the same ophthalmologist who carried out the original screening. In equivocal cases, where damage cannot be excluded or where the extent of damage is difficult to assess, fluorescein angiography is of great value provided this is done within 48 hours of the event.

When an accident is suspected, the site of the incident should be "frozen" until after a biophysical examination. This would attempt to determine whether the power or energy densities which had been present at the worker's eye could have caused damage. This information could be of great value, not only medicolegally but also in relating damage to energy levels and assisting in the development of new codes of practice.

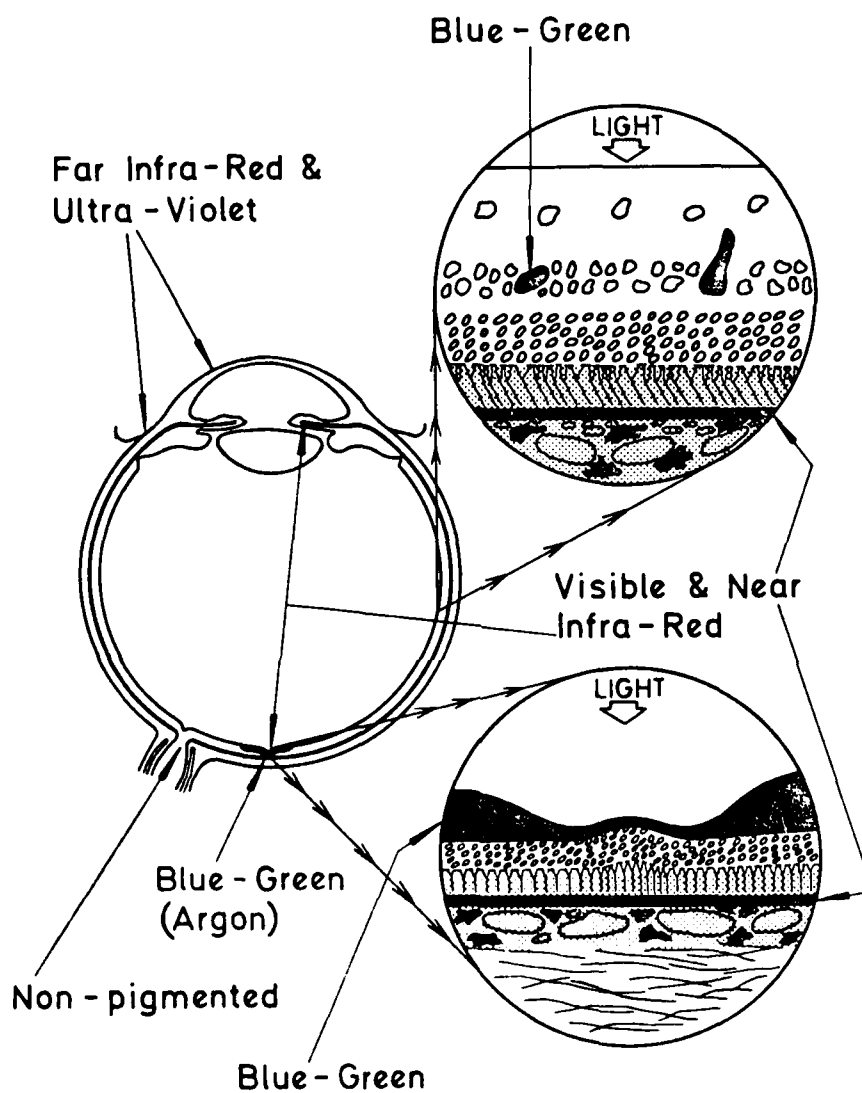


Figure (Brennan). Sites of Injury

Reference

Borland, R. G., D. J. Brennan, J. Marshall, and J. P. Viveash, The Role of Fluorescein Angiography in the Detection of Laser-Induced Damage to the Retina: A Threshold Study for Q-switched Neodymium and Ruby Lasers, *Exp Eye Res*, 27: 471-493 (1978)

MEDICAL ASSESSMENT

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My position on this has not changed since the World Health Organization (WHO) meeting on lasers held in Dublin, Ireland in 1974. At that meeting, Dr. Tengroth, myself, and others drafted the following position (Suess, 1982):

In the early days of laser use, there was a general uncertainty about threshold concepts and associated safe exposure levels. This resulted in a conservative attitude towards possible health problems and, therefore, in the widespread adoption of detailed and regular medical surveillance. In the past decade a large volume of empirical data has been collected concerning the possible risks involved in most common laser applications. In addition to threshold studies, the independent evaluation of medical examinations by the members of the WHO working group led to the following conclusions:

- a. It is unlikely that a near-threshold retinal lesion will be identified as such by ophthalmoscopic examination, even if carried out by an ophthalmologist experienced in laser problems.
- b. Most near-threshold laser lesions will not be detected by the exposed individual when the macular region of the retina is unaffected.
- c. In most cases it is impossible to differentiate between laser-induced and other retinal lesions and pathologies if more than 1 week has elapsed since the possible exposure.
- d. If retinal change is identified, no therapy can be offered.
- e. If gross damage to the retina or significant damage to other ocular components has occurred, the exposed individual will be aware of it.

In many countries, medical examinations are performed regularly or are at least required for personnel handling laser equipment. In particular, an ophthalmological examination is performed, including tests of VA and visual fields, together with funduscopy and sometimes even fundus photography. It must be realized that the expected ocular changes are often subtle, and that without any clear previous history of a laser hazard, an ophthalmologist will have great difficulty in distinguishing an eclipse burn or an early macular degeneration from a laser-induced injury.

From a legal point of view, it will be difficult to relate any ocular or skin change to work with the laser, as the hazardous situation cannot be reconstructed in a precise way.

An epidemiological analysis is a very important part of a laser hazard evaluation, and an assessment of the individual's health status at the commencement of employment in the laser field is needed as the basis for all future investigations.

In the view of the limited amount of information gained from surveillance examinations and considering the amount of time that has to be devoted to them by highly qualified personnel, it is recommended that:

a. Skin and eye examinations should be carried out on laser workers only when a medical examination is a condition of employment. This requirement, however, has to be waived in the case of Class 1 and Class 2 lasers.

b. A medical examination by a qualified expert should be carried out immediately after the alleged occurrence of a suprathreshold exposure. Such an examination should be supplemented by a full investigation of the circumstances under which the accident occurred. Results from both of these studies should be referred to a central agency, and the necessary steps should be taken to prevent recurrence of similar accidents.

Reference

Suess, M. J. (editor), Nonionizing Radiation Protection, WHO Regional Publications, European Series No. 10, page 63, Copenhagen, WHO (1982)

THE US AIR FORCE EXPERIENCE IN OPHTHALMIC SURVEILLANCE

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I am stationed at the United States Air Force School of Aerospace Medicine. Many of you know that we have a nice, integrated approach to preventive medicine and occupational medicine, including an occupational vision program as it affects the flier. To best discuss what we do today, I think it is worthwhile to review the development of laser medical surveillance. Historically, the Air Force was working with lasers in the mid-1960's. By 1968, I was in charge of the laser function of my branch under aerospace medicine. The program was preventive in scope and aimed at laser health hazards control. Our first document was published in April 1969. At this time the ANSI Z136.1 standardization had not yet begun. We participated in the many meetings of the ANSI laser committee in 1969-72, and of course you know that the first ANSI standard was published in 1973.

We were concerned with Chapter 6, regarding medical surveillance, in the first Air Force regulation. It stated that the medical service was responsible for initial and periodic physical examinations of both military personnel and Federal civilians who worked within or approached near the safe eye exposure distance (SEED) of a laser. We did not, and still do not, examine visitors to laser installations. We either keep them out or allow them to visit the installation when nothing is operating. Alternatively, the visitor has to comply by wearing a pair of goggles. Since many visitors wear spectacles, we had to employ coverall goggles. This solves the problem of other staff members who wander in; e.g., secretaries who enter to notify people. There are procedural and engineering safety standards, but this is a different subject. This approach is possible in the laboratory, but the laser laboratory environment is but one of a two-tier system. We must approach general laser use differently. A program to screen 400,000 troops could not fit this protocol, but we can still learn from the laboratory experience. The 1969 physical examinations for preplacement and termination included ophthalmologic, laboratory, radiographic and other tests. It was really an overkill, and I must admit that since I wrote this examination protocol, I will take the blame for it.

One common form [Standard Form (SF) 88, Report of Medical Examination] was used to report all of the tests results. The eye examination included a complete funduscopic evaluation under mydriasis with intraocular tension. We now know that tonometry is absolutely unnecessary. Most of the subjects were young. If in their 40's, I would agree with tonometry. The Amsler grid test was required, and I am still in total agreement with that requirement. It is probably the best test we have and the cheapest. Most of you saw the flash Amsler grid demonstrated yesterday by Dr. Wobarsht. I do not believe that we need the more sophisticated version yet. For our purposes, the Amsler grid is an 8-inch-square graph paper with a dot in the center.

We performed central visual field tests then, and we still perform them as part of our examinations. Today, I do not think that this is necessary.

We initially required color fundus photography. This sent a ripple through the entire medical system, because no clinic had a fundus camera. Soon all the clinics were using this regulation to buy a camera. I have changed my opinion somewhat on retinal photographs. We now recommend an accurate description or drawing by the ophthalmologist, but this requires too many optometrists and professional personnel whom we do not have to perform any mass screening. This requirement is, nevertheless, still in force today. In our own department, we inform remote field units without photographic capabilities not to spend money flying subjects to the nearest fundus camera. You can buy a camera for the price of a few air tickets. Polaroid instant photography is used with the fundus camera. The use of 2 x 2 slides is undesirable, because you cannot see them without a projector and, not surprisingly, they are lost consistently. We attach the instant photograph to the medical chart so that it remains with the patient's medical record. We also maintain one copy for our own small repository. The other copy remains with the patient's medical record. If only one photograph can be taken, I would place it in the patient's medical record. At termination, we repeat this examination. The review of the entire record was initially overdone. We do not have the manpower today to accomplish that unless we are following an individual case of an injury. The 1969 requirement for a complete annual or periodic ophthalmological examination, stressing fundus examination under mydriasis, has been completely eliminated. Routine periodic examinations no longer exist if the initial exam is well done. The termination examination is simple. Two photographs are taken, the VA is checked and the individual answers few questions. That is all, usually 99.5 percent of the charts are closed out then. Only a few need review or referral.

Interim examinations are performed only when the person suspects an exposure or complains of vision loss. We never turn down complaints. This cannot be done in medicine. It is our job to listen to everyone who comes to us complaining with a headache, footache, backache, etc., whether it is real or imaginary. This open-door approach has not generated a large number of visits, only a very few, in fact.

With regard to this morning's discussion of a triservice or single-service standard for examinations, I disagree. I think it would be much too cumbersome. I think that every service has unique requirements; e.g., those peculiar to submarines, airplanes, and field soldiering. The only triservice need is for triservice communication and for a higher level of reporting between whomever is in charge of each of their repositories. I think that you would have all the desired information without the clutter. Air Force personnel will not come up to an AFIP repository or agree to an AFIP department being a repository. Even Dr. Zimmerman's AFIP collection of material is no longer a repository but has been scattered all over the university for training. Originally, we had a repository in our own branch. The Air Force has established the Air Force Occupational Safety and

Health (AFOSH) system, now centered at Brooks Air Force Base, to include an occupational vision program. The AFOSH staff do not have the expertise in all areas, but they have management responsibility under AFOSH Standard 161-10, 1980. Originally, laser eye examinations could be performed only by ophthalmologists, but because of insufficient manpower, the AFOSH standard authorizes both ophthalmologist or optometrists. In the Air Force, occasionally a good flight surgeon may possess the needed ophthalmic examination skills, but that is rare. The Air Force examination stresses the history, best corrected VA distance, and a cycloplegic refraction upon entrance. The Amsler grid, a fundus examination with a description or a drawing, and slit-lamp examinations are also required. The slit-lamp examinations was added in 1968 because of the introduction of IR. The slit-lamp examination blocks any attempt to streamline the examination to permit technicians to perform screening. They can take photographs, but an experienced professional, on the other hand, must use the slit-lamp to evaluate what is being observed. In the 1980 AFOSH revision, I was only consulted on the chapter related to lasers.

Regarding referral of an alleged laser eye injury, the patient must be brought into the normal medical channels. Fortunately, this group is not a large number of individuals. If the patient is a civilian employee, Air Force medical personnel would see him initially, after which he would be turned over to his own physician. An occupationally induced injury would require medical disability action. We also use the SF 88. The AFOSH standard requires that the Occupational and Environmental Health Laboratory (OEHL), and not my Ophthalmology Branch, would maintain a repository of suspected overexposures to laser radiation. In the field, the Air Force bioenvironmental engineer (BEE) initiates reporting, and whether this is performed in 1 day or 2 days is unimportant to us. There is a shortage of BEE's, but one is located in each of the 12 command headquarters. The BEE checks on microwave overexposure and tries to recreate each incident. The laser repository in the Air Force is not currently functional, as is the microwave repository. The latter has a bimonthly printout of all suspected overexposures: a high computer printout sheet. Microwave overexposure cases are referred to us. Laser cases would be treated in the same way if we had any reported.

Routine clinical examinations are performed on all aviators suspected of having visual or other problems which could cause some difficulty in continuing their career. We decide whether they receive a waiver. Our several ophthalmologists and technicians, which we have trained ourselves, see referrals within the regular routine. All referrals and final examinations are handled by our flight surgeon's office or by our clinic. The chart is starred for each individual requiring a special exam, e.g., a laser exam. One star indicates, when an airman is leaving the base, that he worked with lasers and, therefore, needs the special examination.

QUESTION: COL Ranadive: Does everyone come to Brooks Air Force Base for these final examinations?

ANSWER: COL Tredici: No, only those in the local area. Whatever system is decided upon here should be a simplistic, local system. CAPT Wolfe spoke yesterday about the 18 reported injury cases. None of these were in the military, although one was a military academy student. All of the reported accidents were with laboratory workers who work within 1 or 2 feet from the laser. This emphasizes what Dave Sliney mentioned: As you increase your distance from a laser, your chances of receiving a hazardous laser exposure are extremely remote. In the past 15 years, we have had no reported laser injuries in the Air Force, which means that we have either one of the most fantastic preventive medicine systems devised by man or we do not have a big hazard.

COMMENT: Mr Franks: There is another possibility - that the accidents are not being reported.

COMMENT: COL Tredici: If we do not know about it, and if a patient knows he does not have any visual problems, then we do not have any. If the patient is functioning, has not been in for an examination, is not looking for a Veterans Administration settlement, and is still performing his work, all is well. The reason I can state this is based upon the fact that a laser burn in the 1-degree central field will result in a visit to the clinic. You may ask why he would not visit the clinic for a peripheral burn? I would expect that even in this room there are at least 10 percent of you with some large lesions in the peripheral retina which could be seen by fundoscopy. The area of this lesion may be more than any 500 laser zaps that could occur from a laser. Secondly, there are many patients (e.g., diabetics) with literally a thousand laser burns in the peripheral retina who function better because of their laser treatment. In a patient with a very large number of burns, one is often surprised that the laser-induced defects are not even detected on the first peripheral field examination. The poor acuity in the normal peripheral field probably explains why patients do not demonstrate further functional loss. Lasers do not cause cancer, and, if a laser lesion does not progress, as COJ Whitmore had expressed a concern, then perhaps the problem is minimal.

QUESTION: Dr. Zwick: In diabetic patients who have been photocoagulated, ophthalmologists have reported to me that there were no changes in dark adaptation or night vision. Do you agree with that?

ANSWER: COL Tredici: I would not expect that there would be no change at all in night vision. However, I am amazed that the tremendous destruction of the periphery seen ophthalmoscopically cannot be detected in visual field plots without the use of an I-3E target.

COL Tredici (continued): The most important purpose of the laser examination has changed from a medical-legal justification to the need for good baseline data for later evaluations. We have had a very few or no legal cases yet, so this is not a big problem. Finally, we must ask if there is really a laser hazard. The examination may be necessary to find this answer since many injuries may be functionally insignificant; the

greatest laser hazard appears to be in training and in laboratories. There may also be a laser hazard in the field if there will be literally thousands of people pointing lasers in many directions. But this is, as yet, unknown and we have no statistics. With these surveillance examinations, we should have a two-tier system: a thorough examination for technician and laboratory personnel, since this group has all of the present injuries. And secondly, a screening examination for the other mass of 300,000 to 400,000 individuals who could be involved. The screening examination could be minimal but would cover most of the important functional visual tests and be performed without using any professional personnel. This would be my idealistic position at this point.

The next question to ask is: How many detailed examinations are needed? If limited to laser laboratory personnel and technicians, we can probably handle the number without much trouble in the Air Force. By a broad interpretation of present guidance we have greatly enlarged the group requiring the detailed examination. We must reevaluate the makeup of this group. Visitors are excluded, but the mass of individuals using the aligning lasers in the field will have to be excluded because the manpower is not available. I do not think that ophthalmologists should perform this detailed examination at all, as this is expensive and we are limited in manpower. There are only 204 ophthalmologists in the three military services. They should be used as consultants for referral and treatment of those individuals who have been injured. The 500 optometrists and the 400 ophthalmic technicians should carry out the screening examinations, and the optometrists could act as consultants for the technicians. Ophthalmologists are the consultants for the optometrists. Today, we do not have enough authorized technicians, but technicians could be trained in 6 weeks if we had billets.

The next fundamental question is: How often should the examinations be done? We have already discussed preassignment, termination, and periodic examinations. I do not agree with the concept of periodic examinations. A person should be examined only after an accident. This lack of periodic examinations is not serious, because many physical examinations take place throughout the military all the time. In my opinion, one could add new examinations for indicated individuals as a piggyback to the ongoing system. The 50,000 flying personnel already receive periodic eye examinations by the 901 aeromedical technicians, to include VA, a stereo test, and the retinal examination to fly. Air Force enlisted personnel receive a physical examination upon enlistment, and all 10,000 per month enter through Lackland Air Force Base, Texas, where about four optometrists and about eight technicians refract and visually screen them before their 6-week basic training is completed. If the enlistee is destined for a job assignment requiring specialized visual skills, specialized colormetric examinations and stereo examinations are performed on these selected individuals. Therefore, extra testing requirements for laser workers can be added. The entry points for the Army and Navy are so scattered across the country that it would be more difficult to ensure examinations. Laser preplacement examinations do not require a major effort starting from scratch.

Termination examinations are a problem for the Air Force, because most enlistees want to depart quickly, and the medical staff is often willing to let them go without a final examination. Later, if they have troubles, they tell the Veterans Administration that they did not receive a termination examination. However, if we paid more attention to the termination examination, those who had a cursory contact with laser could receive a duplicate of the preassignment screening. The other personnel, mostly civilian employees and laser technicians, will need the more complete laser examination.

Of what should the laser examination consist? I think that it should be simple, preferably emphasizing visual function as much as possible and, if possible, performed completely by a technician with only the supervision and consultation by professionals. It would be nice if it could be executed as simply as an x ray. The minimal screening examination should include central VA, which should be the best corrected in each eye for distance and near. The Armed Force Vision Tester must be operated properly to prevent malingering. It is probably one of our best available instruments if used properly. The Amsler grid should be included whether it is the more sophisticated flash grid demonstrated by Dr. Wolbarsht or whether it is just the simple chart which tests the central 10 degrees. Color vision tests in each eye are worthwhile since they test cones in the macula. Although 10 percent of the enlisted men have color vision problems, this is not important, since we are concerned with a change. I would also include the stereoscopic test because it reveals binocular function. The emphasis in all these tests is to detect a change from baseline. To this point, I have discussed the basic mass functional screening test and this might even suffice, but I think a fundus exam and photograph would be ideal.

Those with complaints would be handled as stated before. At termination those without complaints would be given a repeat of the visual functional exam by a technician. The technician would take a fundus picture of each eye. The fundus photographs would be reviewed by the optometrist. If any changes were noted, that person would be reevaluated initially by the optometrist and, if necessary, sent to the ophthalmology clinic. But this I would expect to be a very small number of individuals - perhaps 1 in 50.

VISUAL FUNCTION TESTING

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I volunteered to do this because I am here mainly as a visual physiologist and I think that a background review of functional testing is in order. To this point, we have mainly discussed foveal visual function testing, because it is so very much easier than testing extrafoveal vision. If a subject has a small peripheral retinal lesion, he would probably not notice as it would not matter very much to visual function. It is extremely difficult to detect a small peripheral scotoma using multiple static perimetry tests. I think field testing is unimportant except for what you can detect with an Amsler grid, i.e., the central part of the visual field. Turning to the fovea, we must ask what can possibly happen after a laser exposure? I think two things could happen.

First, there might be an edema. This might or might not be seen with an ophthalmoscope, but the edema may mean displacement of the receptors resulting in micropsia. This can be tested very nicely using an instrument which was invented to demonstrate micropsiae. I present all of these different tests, not to suggest that they should be used for these subjects, but just to indicate their existence. The micropsia test is complicated and I think it is impossible to consider its use in this context. Another effect of receptor displacement is grid distortion which may be detected with the Amsler grid. The Amsler grid is a very simple test, quickly performed and inexpensive.

Second, there might be cone disfunction, if I may use this broad term. This occurs when the photopic channels do not function as they should. This cone disfunction may be wavelength-specific, which effect has been shown nicely by Sperling and others, using sublesion threshold laser stimulation. This disfunction could be detected using a spectral sensitivity measurement or some form of color discrimination test. The spectral sensitivity measurement is very expensive and time consuming, therefore impractical for screening. A color discrimination test can be simple and I shall consider this later. Most laser lesions will be wavelength nonspecific, since a number of photopic channels will be destroyed. However, I think this is mainly because one has fewer blue cones than red and green ones. Hence, retinal damage will also show up as a color discrimination disfunction. Reduced VA, grid distortion and dark adaptometry changes should also be detectable. A review of a number of other visual screening tests reveals that there are a few simple tests that are both adequate and useful. These were named by Col Tredici; for instance, VA testing, color vision-testing, and grid-testing. With these few tests one can detect a great deal.

I am not sure, however, that I agree with the testing of VA, at both distance and near. Why test near acuity when that is only testing the subject's ability to read at different distances? I cannot understand why it should not be sufficient to test only at distance.

What color vision test should we use? There are pseudoisochromatic plates which are easily administered, inexpensive, and a technician can use them. However, the plates will only reveal a few things. As I mentioned before, there is possibly greater damage to the blue cones and the blue channels for which the usual pseudo isochromatic plates do not test. So, we must either accept a more complicated test or a simple test that will not tell us everything. This is our common dilemma: as always, we must choose between a simple, inexpensive test that does not reveal everything or a more expensive and time-consuming test that tells us more. Dr. Wolbarsht has a nice grid test, which he will discuss later.

Let me just say a few words on VA testing. Yesterday, I heard about several patients tested in the United States with acuities described as 20/20 -2, etc. I know that this notation is used in this country, and that type of notation gives an impression of exactness that the test procedure does not have. I have worked extensively with VA testing and, as all of you know, the simplest way to test VA is by using letters. However, letters have different degrees of legibility. In my own study, I found that the letter L, could be read at a distance 1.7 times farther than the letter G. These discrepancies are much greater than the difference between nearby acuity levels. If one uses Sloan letters, which were selected to be of approximately equal difficulty, this problem is minimized. However, in the standard visual-testing apparatus in the United States, Snellen letters are used, and this problem is significant. For example, the Keystone screener has more difficult letters on one line of larger letters than in the next lower one. If one tests visual letter acuity, one must use letters that have about the same legibility or the results are meaningless. There is normally a random fluctuation in the VA test results. The only way to determine visual letter acuity as exactly as possible is by testing with a number of different type sizes and by making frequency of seeing curves for each letter. This is possible to do. You then choose a standard percentage (50 or 80 percent as you like) and from this you obtain a relatively better measure of VA than normally possible. Dr. Timberlake's machine provides a much more exact VA than routine tests. It is an extremely meaningful test and must be done correctly to provide the maximum information possible. Otherwise, the test tells you nothing. The subject may be tested to have 20/20 -2 one time, 20/15 the next time, and 20/30 the following time. These variations might be quite the same VA tested with somewhat different techniques when there should be no difference at all. These were my introductory remarks.

DISCUSSION

CAPT Blaise: Are you familiar with the chart utilized by the National Eye Institute for its macular degeneration and diabetic retinopathy studies?

Dr. Hedin: No, what chart is that?

CAPT Blaise: The National Eye Institute came up with a new chart for those studies that utilizes a different selection of letters and a standard illumination.

Dr. Timberlake: These probably are Sloan letters.

COL Tredici: I have a comment. I agree completely and scientifically that what you have said is the ideal; but, in the real world these small differences will not be recognized. Tremendous variability is found and that is why we invented a machine, the Armed Forces Vision Tester, which keeps all of these various parameters as stable as possible. The illumination does not vary until the lightbulb burns out. The viewing distance does not vary, the surrounding is not important, etc. We once tried to make standard 20-foot eye lanes but this was not possible. People were painting black, gray, and white, and these problems are so much greater than variations of serifs in a letter. This is where the scientific aspect diverges from the practical/clinical method.

Dr. Timberlake: I would like to briefly *expound upon* that. The greatest source of variability in these tests is not in the eye chart, but the psychophysical procedure; the way in which the responses are collected and the way these responses are analyzed. The advantage of using a machine, especially an automated machine, is consistency. As you well know, no technician is consistent from one time to the next, nor is one laboratory consistent with another.

COL Tredici: We have the least number of errors when we use the machine in comparison with any other method, except when the letters are presented in a random fashion. There is a chart and there is a code with a stipulated procedure for its use. It takes 30 minutes to train a technician exactly how this should be done. Human variation naturally will occur, but as best as we can instruct him, the procedure is performed in sequence and the technician cannot vary any of the other parameters. We have found that nothing goes wrong with the Armed Forces Vision Tester except that the bulb burns out, and this can be administered in Timbucktoo, Iceland, Arabia, or anywhere. I would like to have a better test but I have not found it.

Dr. Hedin: You must agree that the Armed Forces Vision Tester has drawbacks, and you should know what they are to properly interpret the results.

COL Tredici: I absolutely agree.

ANIMAL STUDIES OF LASER EFFECTS UPON VISUAL FUNCTION

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I would like to introduce you to the Army's problem by recalling the familiar illustration of the soldier on the Time Magazine cover wearing his goggles around his throat. That fellow really had no problem in protection. I think that he was protecting his thyroid gland and did not really seem to be concerned about his eyes. He might even be using the wrong pair of lenses. The problem we have is difficult because it involves both developing a new type of protective technology in a very short time frame and convincing our troops of the necessity to utilize such new protection. Past experience, as evidenced in these slides, strongly suggests that we truly need some new ideas in this "softer" area of individual attitudes toward protective materials.

QUESTION: COL Ranadive: Do soldiers not wear protection because the goggles do not fit?

ANSWER: Dr. Zwick: No, because it is more macho.

COMMENT: COL La Piana: The Army has failed to provide a device that the soldier will wear.

Dr. Zwick (continues): Doctors Brennan and Borland provided us with a fundus photograph of a small neodymium laser lesion placed in a diseased human eye, and the patient did not report experiencing a bright green flash.

QUESTION: Dr. Wolbarsht: Did he see anything at all?

ANSWER: Dr. Zwick: No, he saw nothing. Dr. Brennan and Mr. Borland were quite emphatic about that. They emphasized that it was placed in a diseased eye.

Dr. Zwick (continues): Our subject for behavioral testing is the rhesus monkey. We do not always anesthetize our monkeys. This rhesus is an awake, task oriented, trained monkey. It takes a long time to train these animals for Landolt-C acuity tests. The test involves the animals discriminating a very small gap in rings which are randomly intermixed with rings having no gaps. Different psychophysical techniques are used. Most of the data I will present have been obtained with an up-and-down titration technique because we required rapid assessment of visual behavioral threshold. Figure 1 shows a laser lesion in a rhesus monkey eye produced by a Q-switched ruby laser, 1 mJ, into a 1,000 μ m spot. This photograph was taken immediately postexposure. The exposure was designed to destroy the entire fovea in the anesthetized animal and to measure the Landolt-Ring acuity on this animal and compare with a baseline acuity. The baseline acuity was 20/10 and very well-maintained and stable. When we were able to measure the animal, after

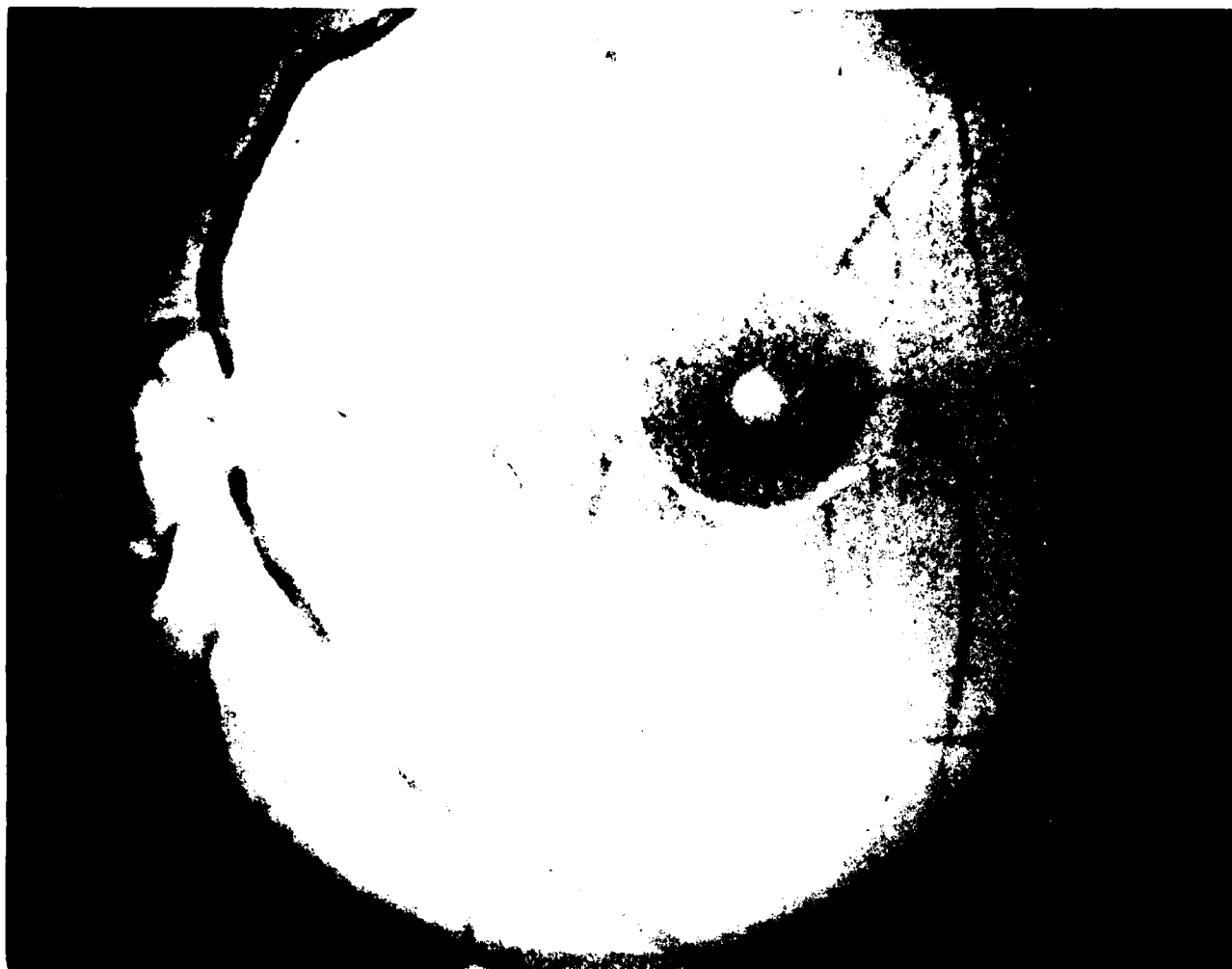


Figure 1 (Zwick). Rhesus Fundus with Central Macular Lesion

the control eye had returned to baseline, 2-3 days later, the exposed eye had a large visual acuity deficit, which increased from about 20/90 to 20/200 over a couple of days. This was consistent with the course of retinal edema, as you would expect. The edema did not appear immediately, but waxed and waned. In some animals the edema cleared early, and the acuity returned to baseline. Other people have found this with different types of lesions, e.g., Mark T'so, Dave Robins, Don Farrer, Bill Ham and several other people. The surprising point is that, despite this much destruction, high contrast Landolt-Ring acuity can return to baseline.

In another kind of study, we tested spectral acuity and spectral sensitivity and found that these measures did not return to baseline when the white-light acuity returned to baseline. An animal 6 months postexposure may demonstrate normal white-light acuity but still have a deficit in his color processing system.

Dr. Hedin pointed out earlier that even if the bulk of the three cone systems have been damaged, acuity can return. Mark T'so showed histologically, for this type of lesion, the retina repairs itself and that adjacent photoreceptors may sheer into the lesion area. Thus, a mosaic of photoreceptors is produced that provide the resolution, but the change in individual cones populations can be revealed as a spatial color deficit (Zwick, et al, 1974).

The necessity to investigate acute exposure effects of small-spot foveal exposure necessitated development of behavioral techniques capable of measuring the immediate consequence of an intense foveal exposure. In Figure 2 the effects of a laser flash-exposure, placed on the fovea by behavioral technique, is shown. The flash exposure source in this session was a 532 nm, repetitive-pulsed, 150 ms exposure, 20 to 50 microns in diameter and at the ED_{50} level for retina burn. While full recovery is not shown, it did occur during this session about 50 minutes postexposure. Although such exposures were capable of producing burns 50 percent of the time, permanent effects of this measure of spatial vision were not easily detected. This result points out a major problem with conventional ophthalmic testing, as transient effects may not persist long enough to indicate that actual morphological damage to the retinal surface had been done.

Even contrast sensitivity functions have not consistently revealed the effects of punctate foveal lesions present in the fovea. In our experiments, ED_{50} exposures can suppress the contrast sensitivity function over a broad range of spatial frequencies (Figure 3). Yet, measurement of permanent change, even with this function, appears to be difficult when using a minimal spot exposure. In Figure 4, we obtained an effect that appeared to be permanent but lasted only several days. Similar exposure effects were rarely produced, although larger spot and longer duration exposure reliably reveal a transition point from temporary to permanent change; i.e., generally 2 to 10 times below the ED_{50} for a retinal burn (Figures 5a and b).

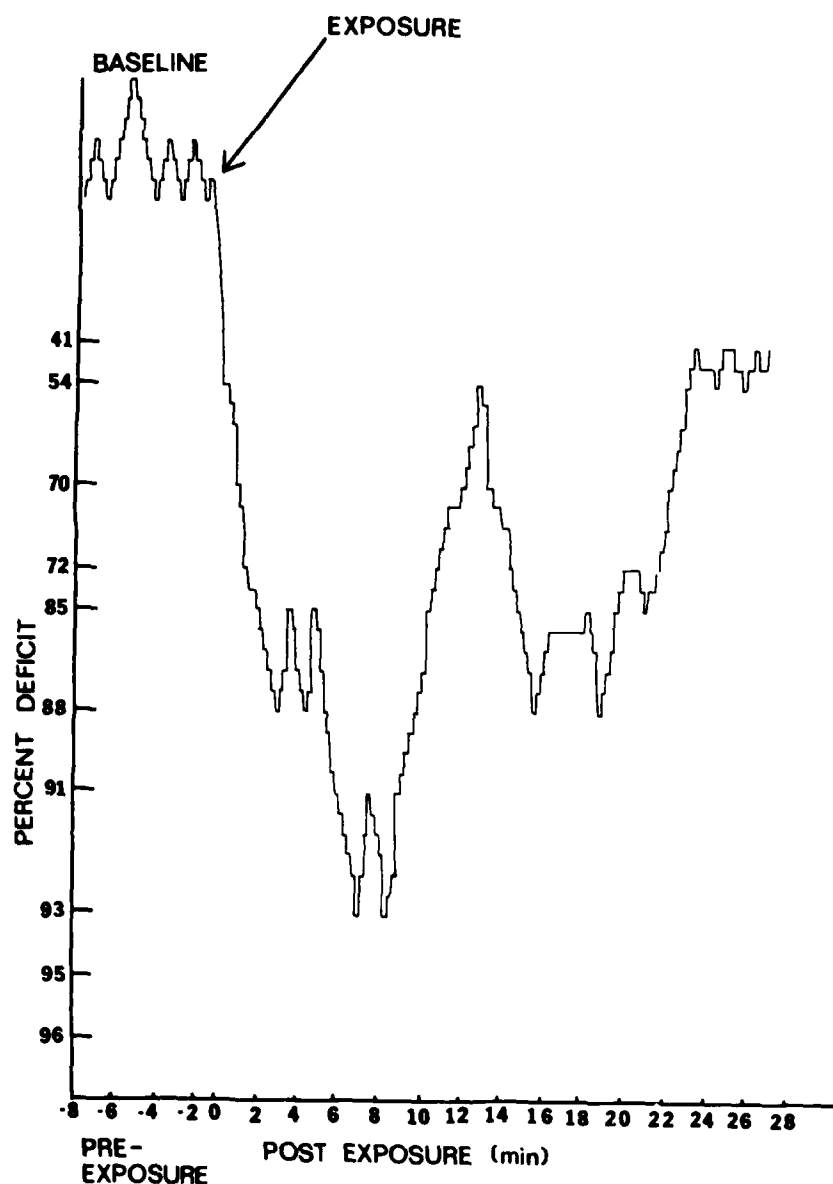


Figure 2 (Zwick). Sample Acuity Tracking Session from a Rhesus Monkey. Following baseline measurements of acuity, exposure flash is presented. Effect of flash on acuity is shown tracked over a 28-minute portion. Full recovery required approximately 50 minutes postexposure. The laser source in this exposure was 532 nm at exposure levels capable of producing retinal burn 50 percent of the time. (Zwick et al., 1982)

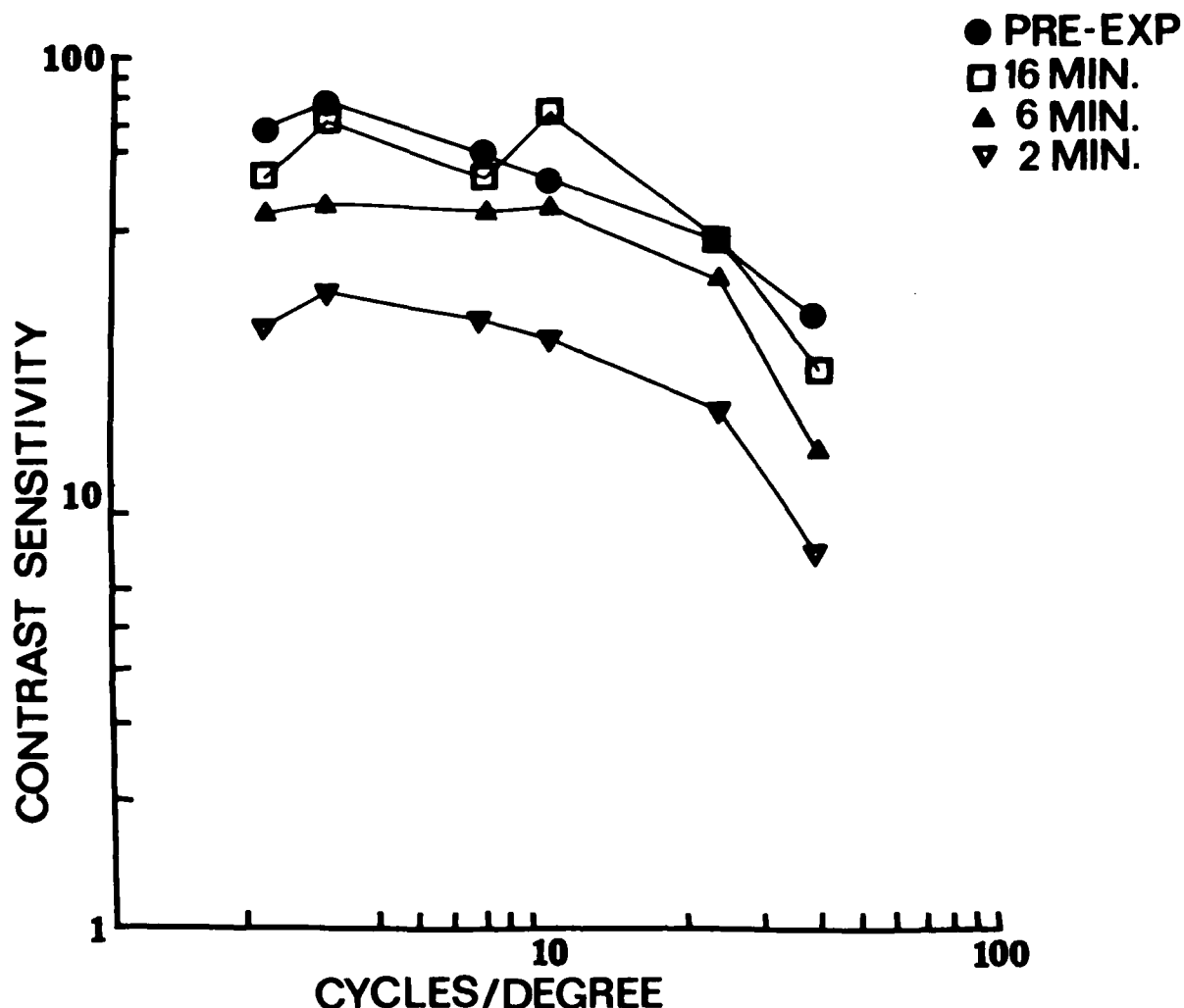


Figure 3 (Zwick). Contrast Sensitivity Functions Before and During Recovery After Minimal Spot Exposure Consisting of Six Pulses Delivered in 150 ms Time Window (20 Hz). The immediate effect is to reduce contrast sensitivity by more than a half log unit across the spatial frequency spectrum. Recovery requires about 15 minutes and appears to be somewhat more rapid for the mid spatial frequencies. Similar recovery functions have been obtained for five animals. (Zwick and Bloom, February 1984)

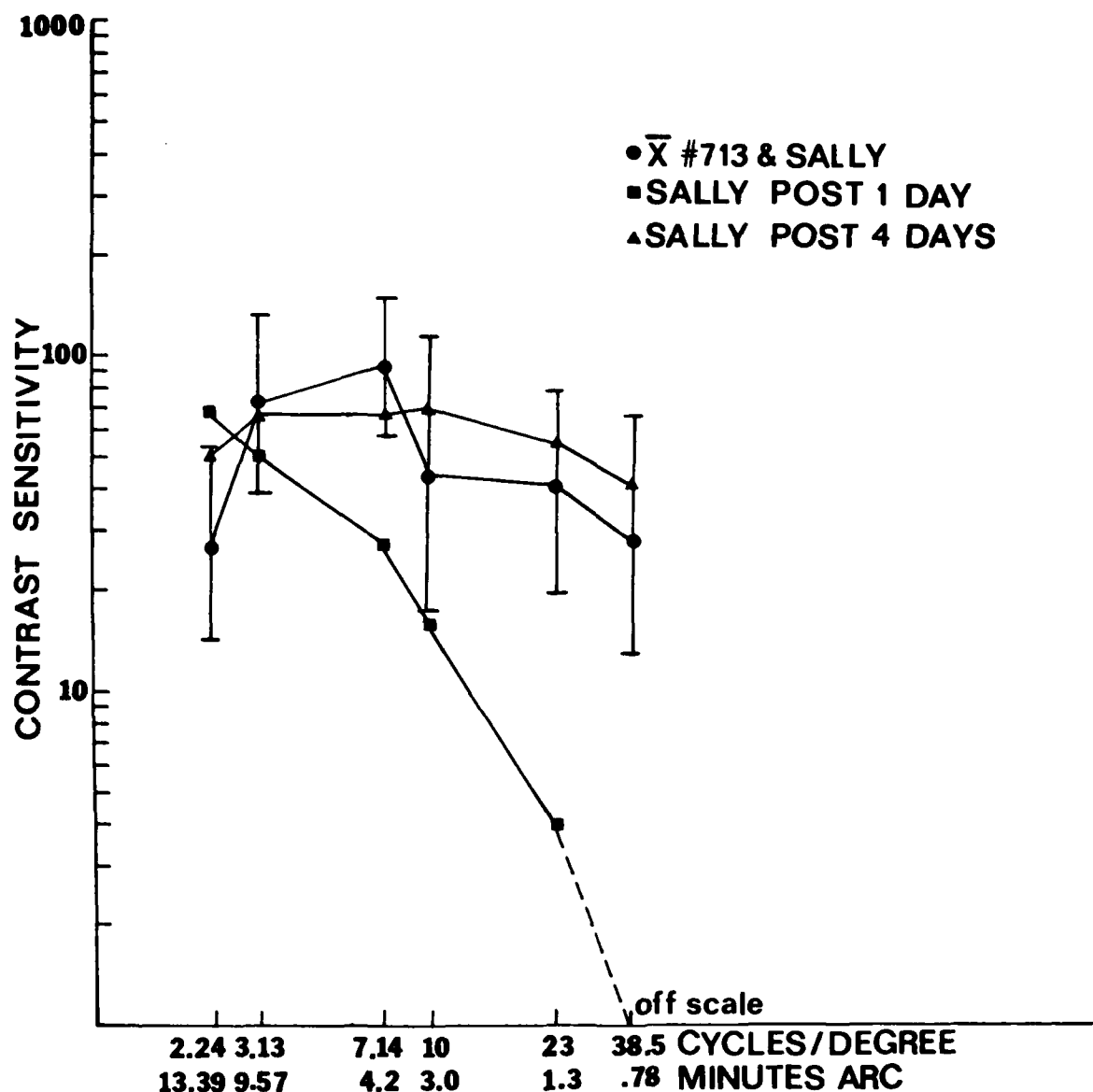


Figure 4 (Zwick). Single Session, Where Pulsed 532 nm Exposure Produced a Quasi-permanent Effect Lasting Several Days Post-exposure. However, this type of effect was not typical even though many exposures were made at, and more recently above, the ED_{50} for retinal burn. Small spot damage processes may be more easily masked by normal visual mechanisms than larger spot exposure. (Zwick et al., 1982)

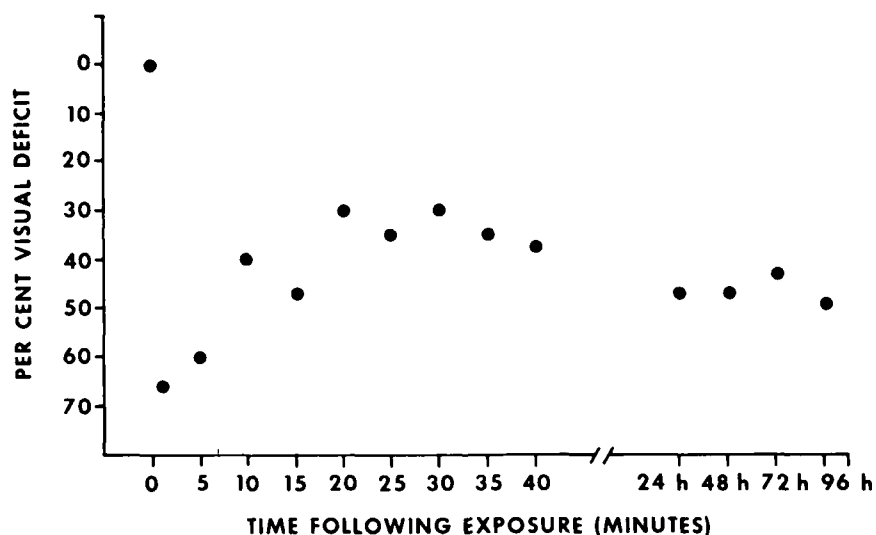
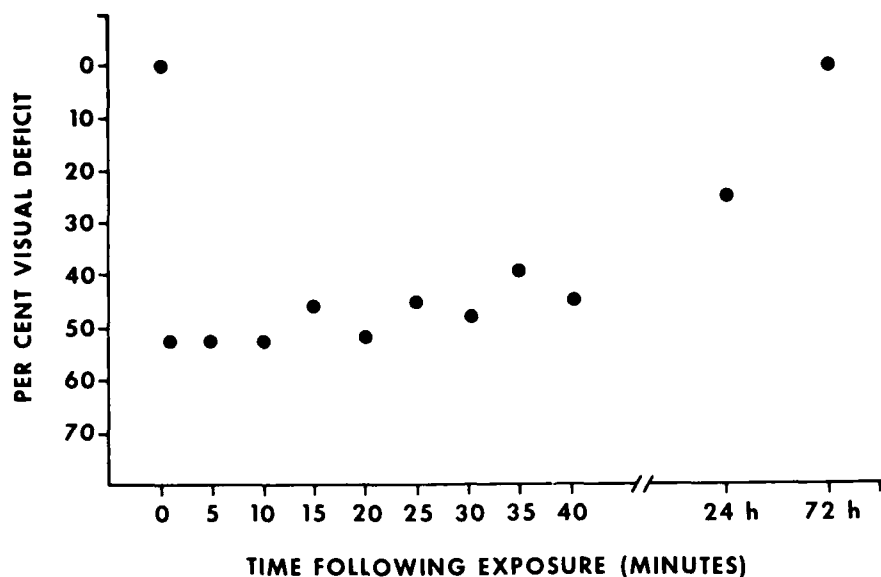


Figure 5a and 5b (Zwick). Changes in Visual Acuity Following Corneal Injury). As exposure power at the cornea increased, a transition level between the transient and permanent acuity deficit was obtained. In this experiment with 100 msec, 633 nm, 150 micron spot size, the transition zone was found at a level about 2.5 times lower than the retinal burn threshold level for a Rhesus retina. At this level, successive exposures were additive requiring a total of four exposure sessions generally before recovery failed completely; i.e., recovery required several months in some cases, almost a year before near-perfect recovery occurred. (Robbins et al., 1973)

In earlier investigations with slightly larger spot sizes (Robbins, Zwick, Hanelin, 1980) we were able to detect long-term, single-pulse flash effects at the MPE for extended source spot sizes (350 microns). Such effects on spectral acuity (Figure 6) and on spectral sensitivity lasted for up to 9 months postexposure. Such effects appear to reflect the same retinal damage processes as have been reported in studies where light exposure produced even more severe changes (Zwick and Beatrice, 1978; Harwerth and Sperling, 1971).

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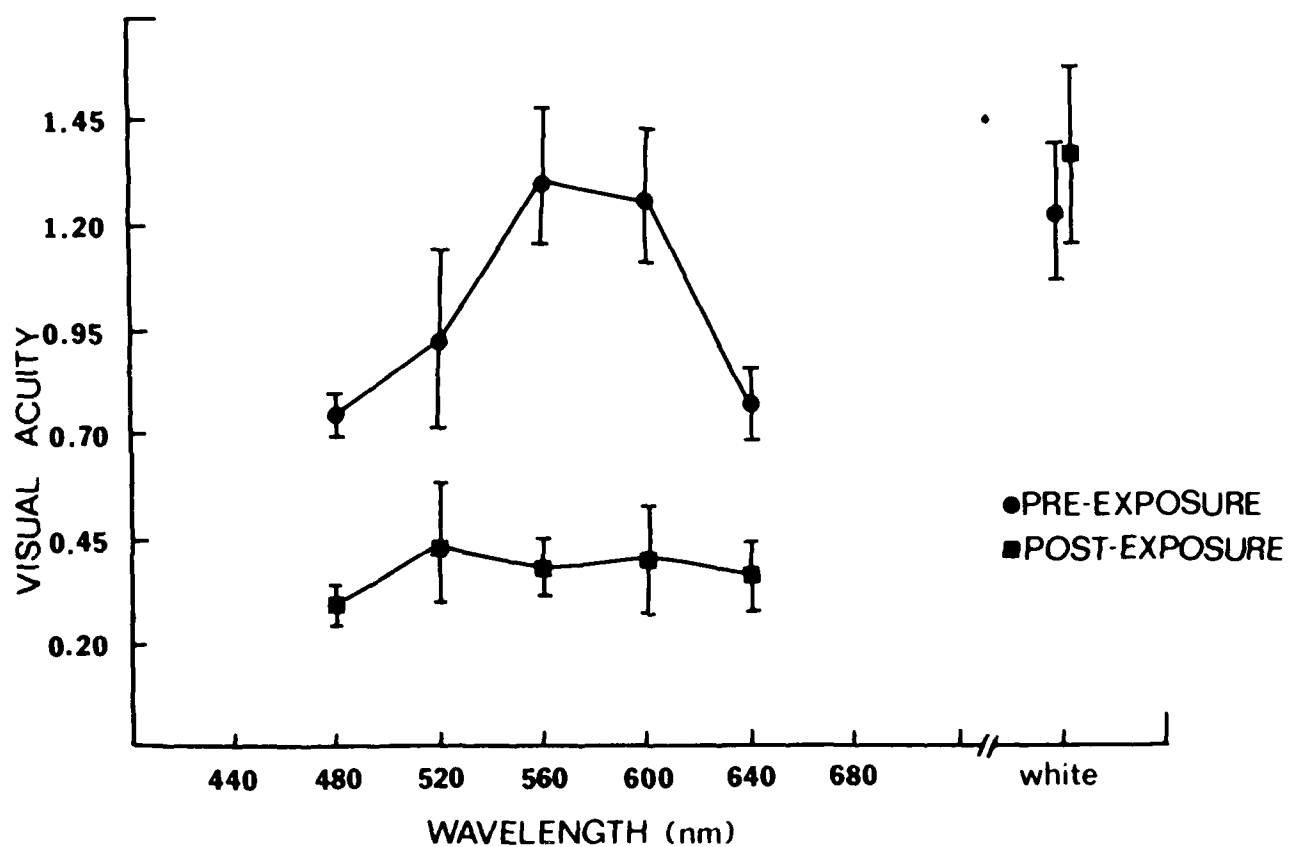


Figure 6 (Zwick). Preexposure and Postexposure Spectral Acuity Spectrum Measured for an Equal Quantum Spectrum. The postexposure function was taken at 6 days. At 9 months the function was essentially unchanged. (Robbins, Zwick, Hanelin, 1980)

DISCUSSION

COL Tredici: For this single case the acuity dropped, as you would expect. I do not understand what happened.

Dr. Zwick: Regardless of the functional change, one can see lesions in the retina, particularly those exposures in the fovea. In some instances the lesions may be parafoveal and not seen. I think the reason that this last experiment may be important is that it represents a case where fairly sophisticated visual function tests were employed. The actual animal was not disrupted in his behavioral testing for fundus photographs until the entire test series was finished about 3 or 4 months later, then he was anesthetized and examined. At this time the lesions were several months old and limited in extent.

COL Tredici: Regarding the total depression in that curve, I have a thought which could be wrong: since this is a 1-degree test, the whole macula is illuminated at two cycles per degree. You depressed the entire macula and the contrast sensitivity function. If you had exposed a larger area, the results would have been different, but you only covered the region that would respond; therefore, the whole curve should drop just like it did. One-quarter or one-half degree spots would not cover the macula.

Dr. Zwick: The acuity in the one monkey returned to normal 3 days or 4 days later.

Mr. Sliney: Maybe the monkey had a cold and just did not want to work that day. How do you know that the monkey was being cooperative?

Dr. Zwick: We constantly check for false alarms. That is a basic criterion. If the false alarm rate changes or goes offscale, testing ceases. These animals generally have a very stable false alarm record. I am not ruling out what you said, Dave; it is a possibility, but unlikely because of our behavioral control procedures.

Dr. Ham: We have a rhesus monkey (Rocky) that is more than 7 years old. Rocky's macula looks terrible. We gave him a rest for 6 months, and then returned him to visual acuity testing, and he shows 100 percent, 20/20 in both eyes. Six months ago, on the first day we returned him to the test, he was 20/20. He scored 99 percent correctly with the Landolt-C's. His macula still appears severely damaged. We plan to retain him to see if he develops senile macular degeneration, but today he sees perfectly.

Dr. Zwick: According to your measures, he could see perfectly.

Dr. Ham: Yes, this does not include spectral sensitivity testing.

COL Tredici: Remember, of the 18 laser accident victims discussed yesterday, only one had very poor vision; almost all of the others recovered to 20/20 (from what was reported). That was amazing to me. Either the scotoma was so small that it was not revealed under testing, and in any case the patient was fine, functionally anyway.

CAPT Wolfe: Most of them recovered unless they developed a full thickness hole.

COL Tredici: That is right. There were only two, I think, and the rest recovered.

Dr. Hedin: One of the interesting points revealed by this curve is the depression in total. This means that using high-contrast VA charts one can detect what will happen. It is not necessary to use low-contrast targets.

Dr. Zwick: But our test was complex because we were using a Landolt Ring which has a combination of spatial frequencies. One cannot jump to the conclusion that low spatial frequencies are unimportant. The Landolt Ring has both low and high spatial frequencies.

Mr. Sliney: From your experimental experience, Harry, can you suggest a functional test that will show laser retinal injury? Or, could you be saying that none are helpful?

Dr. Zwick: I think we must continue the current screening tests and make use of all new information we now have.

Mr. Sliney: Could one use small light-emitting diodes (LED's) which flash the primary colors?

Dr. Zwick: I think many sophisticated tests could be developed; but, the more sophisticated the test, the longer amount of time the test will require to administer.

Mr. Sliney: The vision-screener were developed in the 1940's. Since that time there have been many developments in electro-optic technology, computers, microprocessors, LED's etc. Is it not possible in theory to apply some of your new understanding about vision to the very sophisticated tests that are too lengthy for screening purposes and build a second-generation device to test central visual color acuity?

Dr. Zwick: I think that we shall be forced to build an apparatus like that, whether we like it or not.

Dr. Wolbarsht: This will happen if the instrument is able to detect a minimal change.

Dr. Zwick: I think so.

COL Tredici: At the Air Force School of Aerospace Medicine, we have analyzed two of the more modern automated screeners. One device is from the Health Science Corporation, Phoenix, Arizona, which introduces microcomputer processing with a printout of the results of the standard screener. A better device was developed by Decker at Baylor University. Unfortunately, Decker quit Baylor and went to New Mexico. The Baylor Laboratory had some

good ideas, but gave up on them. It also had a completely automated printout of the results, ready to be put in the patient's chart. These were both analyzed to consider replacement of the current screener, but rejected because of the sophisticated electronics which could be difficult to repair. Our experience with the Armed Forces Vision Tester is that only a spare bulb is needed.

Mr. Sliney: While there are more electronics technicians building automated equipment, they are not introducing creative new tests from the vision standpoint, only automating them to produce a printed record instead of a written one.

COL Tredici: In all fairness, these instruments were interactive, with the patient presenting Landolt C's and repeating incorrect responses.

Dr. Ham: From the data presented by Dr. Zwick, it appears that positive findings depend on when the VA test is performed. If not performed soon after the lesion is created, you may see nothing.

A FLASH AMSLER GRID TECHNIQUE

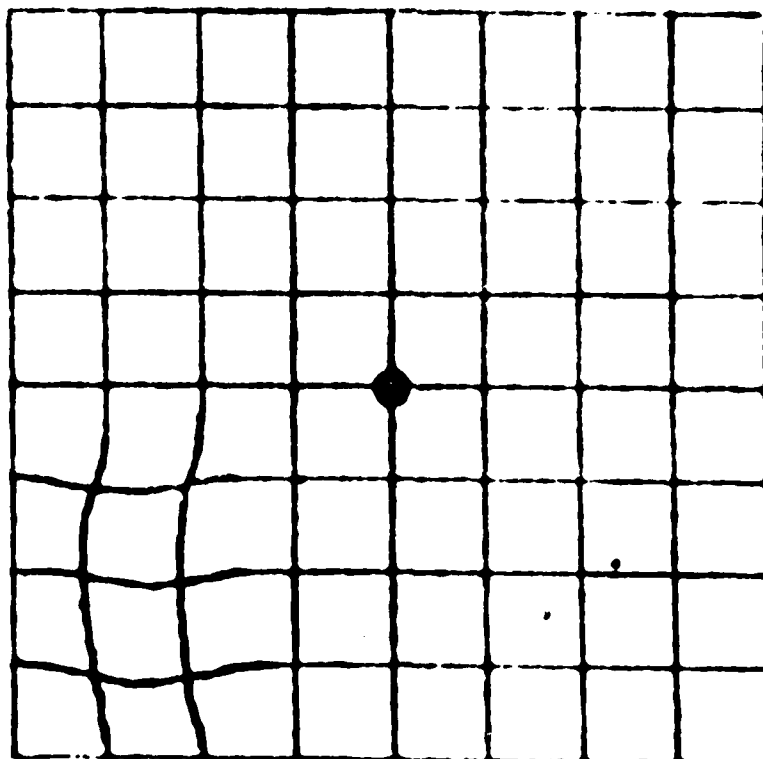
Myron L. Wolbarsht, Ph.D.
Duke University Eye Center
Durham, North Carolina

I subscribe fully to the statements about the necessity for designing functional tests that can operate in a screening mode. Dr. Tredici is 100 percent correct. As Dave Sliney pointed out, it would also be desirable to use more modern technology, but I have a phobia against computers since they seem to always fail when they are needed the most. The hard-wired system is better for screening. Clearly, sophistication is justified after screening has revealed a defect, and then one can use a laboratory test in any degree of sophistication.

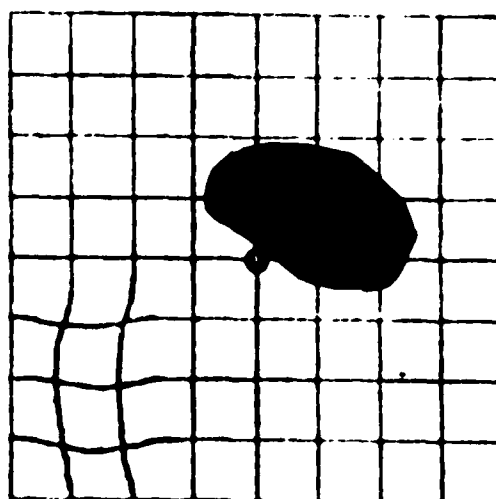
A few moments ago I demonstrated the flash Amsler grid that we built into an old vision tester. This device has been used to test patients having known field defects by COL Lambert, an Air Force ophthalmologist from Wolford Hall, who is currently serving a vitreous surgery fellowship at Duke. I would argue that his qualifications as a retinal expert are impeccable. When he states that there is something wrong with the retina, he has also looked at the retina of these patients and plotted out the defect with a conventional Amsler grid. Later, he tested the patients on this machine to see how accurate it was.

This is a case report (BS) of a woman with a large central scotoma in the left eye and a normal right eye. In summary, she reported all the grid defects with her right eye and missed them with her left.

The following Figure shows another case. This patient (RJ) had a small scotoma in the right eye and a very small distortion in the left eye. The Figure (to the right of the test grid) shows the defect in the right eye, along with the distorted grid in the lower left. This is the defect plotted. He, thus, saw his own defect with no grid distortion. The important point is that the patients can see their own defects and also pick up the designed grid defects. In this way some idea of the accuracy of their reporting is also provided. This Amsler grid test represents the first attempt to incorporate in a screening device a more sophisticated approach to the kinds of functional tests that you will want to use in vision testing. Obviously, in any new tests, two questions must be answered: What functions are to be tested? and how can the test be designed to operate in a screening mode, utilizing the most reliable form of equipment? The technician who may operate the instrument may not be operating at the highest level of efficiency and may be even hostile to the idea of using it. Likewise, the subject taking the examination may not be cooperative enough to draw a scotoma etc., but may be sitting there waiting to finish as soon as possible. These test results can be random in some cases. The objective is to show where the real defects are located with as few false positives as possible. With this in mind, a battery of tests can be designed which will satisfy these criteria. I think this Amsler grid test represents the first step in that direction and has had some clinical verification.



Right Eye



O.D.

R.J. - Saw defect and central distortion

Figure (Wolbarsht). Test Grids and Patient Response Using Amsler Test Pattern

In both the upper and lower charts in this Figure the test patterns are shown reversed; i.e., black lines on a white background, rather than as viewed by the patient with illuminated white lines against a black background.

In each chart, the central black spot represents the fixation light which is left on at all times. When the patient looks into the machine, nothing is visible except for the fixation light. The test pattern, in this case the upper chart, is flashed for 1 ms. The patient is asked to indicate what distortions (if any) are seen in the test pattern and those are drawn on the form as described by the patient.

When the upper test (chart) was presented to this patient, it contained distorted lines bowing out to the left in the lower left quadrant. The lower chart shows the report by the patient (who had a central scotoma) of now only the test pattern distortion, but also a presumably centrally located scotoma. Of course, the scotoma is seen displaced upward when the patient stabilizes on the fixation light.

To assist with accurate reporting in the future, it is planned to have the patient use a video display, with an undistorted test grid shown. An indicator will be controlled by a joystick for rapid positioning. Auxiliary controls will allow indication of blurring, distortion, or occlusion; indeed, whatever is needed to make the display resemble the test pattern perceived by the patient.

DISCUSSION

COL Tredici: Did the patient draw each grid?

Dr. Wolbarsht: No; we compared what they drew on the conventional Amsler grid with our test overlay.

COL Tredici: Yes; but they have to report both their defects and the ones you introduced.

Dr. Wolbarsht: Yes; the test asks whether there was a defect and where it is. Just describe it but do not draw it. One wants to minimize any participation by the subject that requires any activity on his part other than the most minor type. We have considered incorporating a superior type of presentation with a video-game type of control. The patient could actually plot on a heads-up display in the vision tester, but this can be expensive.

Dr. Timberlake: I have tried the stick approach with separate knobs and it was terribly difficult for the patient to use.

Dr. Wolbarsht: You may be surprised how common video games are becoming across America. For today's patient this may be a problem, but not for children.

Dr. Timberlake: It is the older patient population that you are interested in examining.

Dr. Wolbarsht: Yes, but the people entering the Army today are familiar with video games.

LTC Pitts: It should be kept in mind that the Army must screen large numbers of people at many locations. This requires us to go to the patients' units. We usually encounter more cooperative patients since they have not been waiting for 30 minutes to an hour.

Dr. Wolbarsht: I agree that reliability, portability, and other considerations are necessary in the initial design.

COL Tredici: I have one comment to make about Dr. Wolbarsht's flash Amsler grid. The Amsler grid has been used for ages, but this is the first approach where the patient is forced to make a decision. This greatly reduces the time of an otherwise time-consuming test.

Mr. Moss: I wonder if the Army enlistees are sufficiently educated to perform a complete self-test in a system like this?

Dr. Wolbarsht: Well, I wish you had not asked that, but monkeys may be more easily trained (chuckles). Seriously, from my experience with the clinic patients at Duke and driver applicants in North Carolina, an entire battery of tests can be given in a very short time to illiterate, semicooperative people in a way that will indicate visual function to any degree of subtlety that you require. The test will only indicate that something is wrong with some aspect of visual function. Further diagnosis requires an expert using other tests, such as fluorescein angiography, etc. To produce documentation in a reliable, quantitative manner can be accomplished even with a portable instrument. Development will be an expensive proposition, requiring extensive validation. Validation for each one of the tests is necessary because each test is different in nature. Nevertheless, incorporating some of the ideas that Dr. Gunkel showed us for color vision could be adapted in a simpler type of machine in a screening mode. Dr. Gunkel's tester would be a second-echelon laboratory instrument to document more clearly a defect which shows up in the screening mode. To summarize, by the proper selection of particular visual parameters and tests, any particular type of hazard exposure to lasers or chemical intoxicants can be tested.

MEDICAL SURVEILLANCE REQUIREMENTS IN THE ANSI Z136 STANDARD

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Allied Corporation
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COL Ranadive: Dr. Wolbarsht will now explain ANSI Z136.1 in Dr. Hathaway's absence.

Dr. Wolbarsht: The ANSI Z136 committee is trying to revise the section on medical surveillance. The committee has now developed a firm position that absolutely no periodic examinations of any kind should be required. It is very interested in some kind of documentation or epidemiological study regarding delayed effects of exposures to high levels of visible light, particularly in the blue end of the spectrum. That should tie in with the findings of Dr. Ham, Dr. Sperling, and others, which show the loss of sensitivity in the blue end of the spectrum to be connected with photochemical damage. Such damage might be particularly apparent in the macular region after exposure to a high energy laser, or even multiple subthreshold exposures, or from viewing high intensity holograms. The appendix to the new ANSI standard will emphasize functional examinations that are within the reach of the average industrial concern, a small-scale governmental organization, or even the consumer - tests that are effective yet not too expensive to perform in terms of both money and the time the employee is away from the job. We started out with the idea that the laser safety examination would be incorporated into job fitness tests. There are two objectives. First, to ensure that this person has proper visual function for his occupational tasks. For example, in the military, target designator operators may require a more than adequate visual acuity, night adaptation, etc. Pilots may require the best dynamic visual acuity. Along with the occupational suitability test, additional tests which could detect pathology would mimic the kind of injury that you would expect from exposure to the hazard. For example, the laser test should detect macular changes that would appear similar to the results of a laser exposure, to preclude false claims. We recognize that funduscopy does not tell whether a lesion is caused by a laser; so again, functional testing is the only cost-effective approach. We recognize that this functional test is not a medical examination. We are not trying to test total visual function or trying to detect a malignant melanoma or glaucoma. Glaucoma is present or a malignant melanoma is present and does not interfere with visual function at the time of examination. This approach is important from a liability standpoint. We are trying only to ensure proper visual function for assignment. It must be made clear to the employee that this examination is not a medical examination, and is not to tell him whether he has ocular pathology, but merely to ensure adequate performance and to rule out very specified ocular pathology to rule out liability later if he turns up with glaucoma. It is made clear to the subject at the time of testing that if he wants to find out if he has healthy eyes, he needs another kind of examination.

This test may given as part of a general physical examination, the induction examination, but that is another matter. The eye test is just for selected people doing selected jobs. In the Army, maybe everyone will be exposed to laser radiation and everyone is tested. But the ANSI standard defines an identifiable group of people, an identifiable group of visual requirements, and an identifiable group of hazards to which they will be exposed. A circumscribed list is provided of types of effects that might occur from these hazards. Some of the recommendations obviously apply only for the industrial employee and would not apply in the Army. The last statement is just to deal with unions with whom this examination may appear as if you are trying to eliminate some group of people. One must be careful (probably in the Army, too) to explain that the physical examination is for physical performance and not for other screening purposes.

I will add one statement about visual acuity to support the arguments of COL Tredici, Dr. Harry Zwick and Dr. Hedin. The letter test for visual acuity is probably as bad a test for visual acuity as you can have, for several reasons, and I will mention some that have not been raised yet.

First, testing for letters not only tests your ability to solve certain visual angles, it also tests your ability to recognize letters. My favorite story on this subject relates to the duck blind where a guide and a novice are both looking at ducks coming in from the horizon. The guide looks and says, "I see two mallards coming in over there." You look and see the same thing he sees. You have just as good visual acuity measured with Snellen letters or by any other test, but you cannot recognize two mallards. He does not have better visual acuity than you, but he recognizes those small groups of ducks of a certain variety because of the way they are moving, the elevation and speed, the way they flap their wings or any clue such as that. He can tell what they are, but you require a lot more experience to do that.

In the same way, the number of clues that one needs to recognize letters as an experienced reader are fewer than the person who is just learning the alphabet or who may use a different alphabet. This is why visual acuity has to be tested in the "illiterate fashion" to be worthwhile as a means of documentation. I might add in this respect that different cultures use letters in a different way. For example, in English if you read Roman letters, you can cut off the bottom half and still read a sentence pretty well. If you read Hindi, which has all detail below the mid-line, and cut off the bottom, you cut off everything of value; so the person experienced in reading the Hindi alphabet would look at the bottom of the letters and the information there, whereas we would look at the top of the letters. So Snellen letters are not equivalent for different cultures or different backgrounds in terms of legibility. One simply must use an illiterate type of examination. I think the checkerboard is a very good one, but the Landolt-C is almost as good.

My second major point is that visual acuity, as usually tested, has such high contrast and is presented at such a high luminance level that any visual difficulties are minimized. The variability is therefore more a state of the equipment, or the way the patient feels that day, and how the examiner presents each task to the patient, rather than the patient's difficulty in seeing the letters. A better test method would employ a lower contrast and lower illumination level, thus making the test more difficult and the interpatient variability more easily discernible. There are differences between people with high acuity; e.g., at 20/10, 20/15, 20/20. It is in this range where one wants to see the differences, because this is the documentation needed to discern subtle differences in macular and foveal function. I spoke earlier about some of the tests that we tried to develop in this regard. In addition to the Amsler grid, we attempted to develop a better color vision test, and we believe that a contrast sensitivity function test may be possible. All of these tests may be incorporated into a machine eventually, if enough bright people are willing to work together on this problem. There has yet to be a sufficient effort to develop screening tests for particular visual functions. Recent developers have concentrated either on hardware (e.g., building a computer into it) or visual function. Those interested in the optics and visual function measurement have not generally been interested in screening modes. Vision researchers have been interested in laboratory testing to document every little wiggle in the curve. We want an instrument that can be used in a screening mode, but nevertheless is sufficiently sophisticated in design not to requiring sophisticated input from the performer. I think the ANSI standard is moving in this direction, and hopefully we will have your assistance in this effort.

DISCUSSION

COL Ranadive: Any questions or comments?

COL Tredici: I wish to make one comment on records and Polaroid fundus photographs. The Air Force has about 15 years' experience with his process and each photo is retained in an envelope inside the patient's folder. No fading has been noted.

Dr. Wolbarsht: The prints made 15 years ago are not of the same type being made today because shortcuts due to competition have compromised quality.

COL Tredici: I know, but we do not need a photograph for an eternity. If it would last over a 20-year career, that would be sufficient. Upon each record review, e.g., at the 5-year period, any fading photograph could be replaced by a new one.

Dr. Wolbarsht: Yes, but that is the baseline photograph. How can you duplicate it?

COL Tredici: This would be acceptable for a normal retina.

Dr. Wolbarsht: Unfortunately the government has a habit of buying low bid items. With Polaroid, Kodak® and Fuji® now producing instant photographic materials, another entry may receive the government bid and deliver very poor film.

COL LaPiana: I have the opposite experience of COL Tredici. I do have Polaroid prints that I took years ago that definitely degraded with time. I have always been impressed with the lack of sufficiently fine detail, particularly in the foveal region. I vastly prefer the 2X2 slide. One can project at it, copy it, or make a print from it, and it occupies less space.

Dr. Wolbarsht: The SX-70 film has terrific definition for print film and is probably the best, but unfortunately the fundus cameras do not use this type of film. We might add here that it is not necessary to take fundus photographs with the most expensive equipment, since the limiting factor in resolution is not the camera optics, but the film quality in this instance.

COL Tredici: If photography is unreliable, our biggest stumbling block, will be to circumvent the need for photos. You cannot force the examiner draw adequate pictures in a mass screening.

Dr. Wolbarsht: Pictures are only drawn during a mass screening to document anomalies. If only a functional test is employed and it shows a decrement, then a complete workup with drawings or fundus photograph can be carried out. I was impressed, by the way, with Dr. Hedin's presentation. He has provided a rationale to include a color vision test -- not as a reason for testing color vision -- but, rather, as a diagnostic sign for macular disfunction, e.g., to detect a blue defect or something similar.

COL Tredici: The defect may not be in the blue; any defect picked up will show a problem in color vision, and it will be in one eye. In one eye it is not congenital.

Dr. Wolbarsht: It can be congenital in one eye in women.

COL Tredici: If in one eye and not in the other; this is very rare.

COL Ranadive: The following summary paper of these proceedings was kindly prepared by Dr. Tengroth. Although the agenda calls for the Chairman's closing remarks, Dr. Tengroth's summary shall be the remarks. When we comment on this summary, please keep in mind that the primary purpose of the symposium was to revise (if necessary) the current Army policy on medical surveillance. At the end we shall review the present policy in each aspect to determine if a change is needed.

PROPOSED SUMMARY OF THE SYMPOSIUM ON MEDICAL SURVEILLANCE
FOR PERSONNEL EXPOSED TO LASER RADIATION

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1. It has been clearly stated that the eye's fundusconic picture cannot tell if a retinal lesion is caused by a laser beam, neither can such a cause be excluded.
2. Only with a history of exposure to a laser beam above the MPE, and then in the very acute stage, a laser lesion can be diagnosed.
3. As the purpose of medical surveillance is for liability reasons and not for epidemiological reasons, the functional tests are the most important. Even if funduscopy is of such a limited value in this respect, a central fundus photograph is of value to have a baseline.
4. Functional tests as well as fundus photographs could be performed by paramedical personnel.
5. A pre and post assignment test should be performed.
6. A parallel could be drawn from the tests of patients with rheumatoid arthritis who were on the drug chloroquine, where the fundus picture is not characteristic and where functional tests both for therapeutic and liability reasons are performed.
7. Ophthalmological examination should only be performed if the functional tests are abnormal or if the story of a laser hazard is obvious or the fundus photograph is showing abnormalities known to ophthalmologists as treatable disorders.
8. In cases with a clear laser burn of significant depth, a followup with fundoscopy, fluorescein angiography, etc., on a yearly basis to exclude neo-vascularization and secondary pathology.

DISCUSSION

COL Tredici: In reference to statement No. 1, can the retinal experts here agree that this statement is valid? I would like to point out that if you had a patient with a large, old lesion - nice, round and delineated with a hyperpigmented border - you could not positively state that this was or was not due to laser exposure. It is not too often that an isolated lesion will exist. A fresh lesion can be identified.

COL Whitmore: It is the factor of the elapsed time after exposure which is the determining factor. With time, remodeling of the lesion can take place, with alteration in pigmentation and contour. Your point is well taken, but because of alterations it should be indicated that one cannot tell with certainty that a lesion is caused by a laser but, on the other hand, one cannot deny it.

COL Tredici: Okay, we can agree with statement No. 1, but it then appears that this makes our objectives seem hopeless.

CAPT Blaise: We could not say with surety from a single visit that a retinal lesion was caused by a laser beam, but over time, if followed, there could be some degree of confidence.

COL Rosenberg: Think of this in the context of being on a witness stand with a sharp lawyer for the plaintiff handing you a photograph and saying: "Doctor, here is a series of photographs. Pick out the ones that have laser injuries and the ones that do not." In that context, I think statement No. 1 is still valid.

COL LaPiana: I agree.

COL Ranadive: Does everyone agree in principle with Statement No. 2? I see no objections. Statement No. 3 is an interesting statement. Even if funduscopy has such limited value, a central fundus photograph has some value as a baseline. Even if we, as a group, agree that this is so in principle, then all of you can quickly realize the practical impact in terms of resources. One might wish to give more thought to that. I interpret this statement to mean that a central fundus photograph is the best way to record or document a fundus baseline examination. If this is so, then it must be decided how this policy could be implemented in terms of a program and resources.

COL Tredici: First, a photograph is not the best exam. A fundus exam using the trained human is best, because he can see more. Under the prevailing system, with available methods and manpower, a fundus photograph by a technician is the best we can do in a limited way. Second, the fundamental question is, should a photograph be a part of the baseline at all? To answer this question we lack the knowledge of this screening exam's validity and reliability. What is not known about any surveillance program, including the Air Force's program is how many patients with problems fall

through the net (3 percent, 1 percent). I would suspect very few patients with significant problems would not be detected by our surveillance program, even if they did not have a fundus examination. I am reluctant to forgo the fundus exam if they pass the functional tests. There may be some liability in this approach. If Workers Compensation paid each time something was bad, the plaintiffs would win 98 to 2 at the least. Are we willing to bargain if we have to do that?

CAPT Wolfe: I would like to pose the question: Should we photograph only patients with retinal lesions or everyone who is normal?

COL Whitmore: What is normal? A lot of examiners say that parafoveal lesions are normal, and if the patient is functionally normal in the fovea, the patient is normal.

COL Tredici: The point is that we would like to dispense with the fundus examination and have a technician do everything without the examiner. To do this, and have a record which would stand up, may be too far in the future and only the next phase. If examiners evaluate the fundus, no photographs are needed. The initial question of a baseline remains, and most of us agree that everyone should be photographed.

COL Whitmore: Where, by whom, and with what types of equipment will this be accomplished?

COL Tredici: It is a big headache.

COL La Piana: It is impractical.

COL Whitmore: If a person enters a laser use program and has a known lesion, it has to be documented.

CAPT Wolfe: Absolutely!

COL Tredici: How are we going to find laser lesions under the present system, anyway?

COL Ranadive: It is extremely difficult for me to interpret the meaning of Dr. Tengroth's statement No. 3. If fundoscopy, per se, is not very important for medical surveillance, but is nice to have for a baseline in the evaluation of a retinal lesion suspected to be caused by laser, we can say that it is nice to have but, given the practical limitations of resources, impractical. Dr. Wolbarsht and Dr. Deeter have argued that there may be a limited group of people of epidemiological interest. One could select a certain group of extremely high-risk individuals for study. This is just like having baseline chest x rays for future cases. If this is done, a central fundus examination for documentation of the record would be needed.

COL Tredici: I would argue that we now examine the most highly vulnerable since we have the capabilities. All the people we see now in the Air Force are in the high-risk group. But if you do not alter your risk group criteria, you shall have to photograph hundreds of thousands of individuals, and that is absolutely impossible. We should modify the original exam, to enhance it slightly, to demonstrate that we have done everything that is humanly possible today, despite the lack of total understanding.

CAPT Blaise: The question remains: How many would enter the three services whom we would have to photograph every year? This is not the total number of people now in the service.

COL Ranadive: We are still talking in terms of hundreds of thousands, surprisingly quite a few.

COL Rosenberg: There has to be at least 100 to 125,000.

COL Tredici: Now wait a minute! Every soldier need not be examined, only Army aviators, etc.

COL Ranadive: However, if one only selects a soldier at one stage of his career, it could prove very hectic.

COL Tredici: I see the problem. It appears that our system is really better in this regard. When everyone enters the service through the same door, you have a tremendous opportunity to perform any medical test on him. The Army enlistees are scattered all over.

COL Ranadive: There is no doubt about it. For example all of us know the problem of trying to obtain good quality examinations at AFEES's. Even a simple blood grouping test can be difficult.

Returning to the Tengroth summary, statement 4 states that functional tests as well as fundus photographs could be performed by paramedical personnel. I think this relates also to the fundus photograph and how we improve the state-of-the art.

COL Tredici: Color and functional tests could be performed completely by paramedical personnel. They do it now with testing machines.

CAPT Blaise: There is no question that the tests can be done readily by paramedical personnel. COL Tredici and I are highly involved in the training of ophthalmic medical assistants.

COL Ranadive: Can they take fundus photographs as well?

COL Tredici: Yes, everything, and we certify their qualifications.

Dr. Zwick: In terms of functional tests, I think you may not encounter problems in training paramedical personnel on the present screening test, but you may encounter problems as the tests become more sophisticated. The ophthalmologists must utilize and train their staffs to run these tests.

COL Tredici: It is more difficult, but we receive people with IQ's better than the norm today.

Dr. Zwick: To give a test, like a contrast sensitivity or acuity, at different contrast levels, a set of instructions and some rationale would have to be given to these personnel.

COL Tredici: We must design the sophisticated test to require unsophisticated operation.

COL Whitmore: For the 91Y course (ophthalmic technicians) at Fort Sam Houston we are now engaged in initial efforts to put fundus photography into their curriculum. This step was for other reasons, but has already been taken.

COL Rosenberg: The 91Y technician is located in a speciality clinic and is not involved in the entrance exam.

COL Ranadive: The principle here is that fundus photography can be taught and can be performed by paramedical personnel if we should decide that this is needed.

COL Tredici: However, the current technicians do not yet have adequate training. That opens a new problem. One has to double the number of ophthalmic technicians; one must obtain authorization and that could be difficult.

Dr. Zwick: The Army and the Air Force give audiograms, which have a complicated rationale behind them.

COL Tredici: But the audiometer is automated.

COL Rosenberg: Not all are automated, and we have had our share of troubles.

COL Ranadive: Dr. Ohlin of USAEHA is here and he is an expert on the quality of audiology training and testing in the Army. I shall ask him to summarize his experience in that field.

Dr. Ohlin: I have been sitting here for 2 or 3 hours trying to draw some analogies between our two areas of functional testing. We currently have a sufficient data base to analyze the sources of data variance. "Automated" does not apply to our audiometers. This word often rolls off the audiometer salesman's tongue. We have found so far that one of the major sources of data variances is to be found in about 3 percent of the 150,000 audiograms that we have looked at in the last 2 years. We suspected that shortcuts in the test procedures were being taken by some personnel, resulting in falsified records. The culprits surprised us. Most were 91U ENT technicians, the best trained and most sophisticated people. For example, they would alter test results so they did not have to perform followup testing. Therefore, if you employ any kind of functional testing, you must expect some falsification of data, and quality control measures must be initiated to pick it up. We sensitize their supervisors to it. This is just one source of data variance that we picked up by reviewing the forms.

COL Whitmore: If they try to substitute a fundus photograph, we can identify it by the vessel signature.

COL Ranadive: Dr. Tengroth's statement No. 5 states that pre- and post-assignment tests should be performed. The word "assignment" has tremendous practical implications. Does one mean by assignment, the point when a soldier arrives from one installation and participates in a test at another, such as Fort Hunter Liggett or Yuma proving Ground? or does one mean a soldier assigned to a unit who stays there for 3 years to be involved in force-on-force training with laser designators and rangefinders? or does one mean those MOS's that are involved with the use of laser designators and rangefinders as specified when they enter the service and at termination? Based upon the previous discussions, I am leaning towards defining the "assignment" as when they enter service and at separation. Anything less than this, I think, will result in many tests, but not necessarily good ones.

CPT Stout: With this in mind, based upon statement 3, it would seem that one of our main concerns is liability. Ms. Norman, the attorney, seemed to indicate that whatever happens to a military crew is an added financial liability only when you do not keep them informed. For a situation as occurred at Fort Hunter Liggett, where 900 personnel were involved in the test and had a very remote chance of exposure an significant damage, only a list of names and SSN's need be maintained should the need arise to contact them later. On the other hand, RDTE personnel are fairly stable in assignment and have a significant chance of exposure. They should be followed very closely with fundus photography, ophthalmoscopy, and detailed functional testing to see what trends develop.

COL Ranadive: I think we must return to statement No. 5.

CAPT Blaise: With regard to pre- and post-assignment testing, we may take an analogy from the Navy's ionizing radiation program. The individual is tested not when he enters active duty in the Navy, but just before he enters the actual nuclear training. This could effectively narrow the group to be tested.

COL Tredici: Let me remind everyone that if we had a simple, new type of macular function test, without photography, to be given only to laser workers, it could be given as the pre- and post-assignment examinations. This great new test could demonstrate up to a 99.5-percent "clean bill of health." We do not care if the soldier is shipped out to Fort Huachuca or elsewhere as long as he remains in that career field. If he enters a different career field, or no longer will use lasers, he should receive that test again. Otherwise, too much time can elapse before separation to be useful.

COL Ranadive: I presume that the reason for such testing is that it is possible for an individual to have a laser injury.

COL Tredici: No, I am referring to an eye problem which a plaintiff can later claim was a laser injury. But we admitted in statement No. 1 that we could not differentiate a laser injury from other etiologies.

COL Ranadive: The problem occurs when he leaves the service and has any decrease in visual capacity. Could he claim a lesion that could have been caused by a laser regardless of whether we tested him? Given the current legal rule, chances are that would receive compensation.

COL Tredici: This is hypothetical, but if the functional test were able to pick this up at entry, then after 3 years in laser work he cannot claim compensation.

COL LaPiana: It appears to me that the one difficult fact that we continue to ignore is the size of the patient population. If we have about three-quarters of a million men in the Army, almost everybody in the Army is going to be exposed to lasers in some way or another within the next decade. I submit that it is much too large a group to even consider for fundus photography and complete examinations. Some sort of simple screening device is needed that can be incorporated into the induction process and then repeated upon separation from the Army, whether that is 2 or 20 years later.

COL Tredici: Under that system we will have to accept that there will be many alleged laser injury claims difficult to differentiate.

COL Ranadive: Well, I think all of us would agree that no amount of medical surveillance, whatever the type or frequency of test, will, in itself, prevent laser injury.

Dr. Wolbarsht: One point brought up yesterday was that anyone alleging a previously unreported injury with an old lesion must explain why he did not report it earlier.

COL Tredici: That may be sufficient for us, but that will not suffice in our legal system today.

Dr. Wolbarsht: I am not so sure that is so. At one time the lesion was fresh, and he must explain why he did not report it then. If it did not disable him for 5 years, what would be the big problem at the time of reporting?

COL Rosenberg: He could always claim a delayed effect.

COL Tredici: If it occurs during service, he will collect.

COL Ranadive: To a certain extent, if it is service connected, it does not really matter. If he has an injury, he will collect later. Now, let's turn to current Army policy in AR 40-46 and TB MED 279. Consider, for the time being, active duty military for discussion purposes. In terms of "preplacement," upon entrance on active duty they will receive an AFEE examination, including both visual acuity and some degree of fundus examination. Upon separation, they receive the PCS examination. For a suspected or confirmed ocular exposure to hazardous levels, this is certainly performed right now.

As far as the many troops involved in the field test and evaluation of particular equipment, or force-on-force training, it should be necessary only to ensure that visual acuity was tested recently and at the end of the test, irrespective of whether somebody complains. I would like to stop these evaluations of the fundi of 900 people. We should emphasize only visual acuity tests, and then the only further examination would be for those who think they have been exposed during a test.

COL Tredici: I agree with that approach. They do not even require an exam. The medical report just should be checked (the SF 88) to see if a visual acuity test has been performed recently.

COL Ranadive: This would be the same approach we follow for overseas assignments.

COL Whitmore: Yes, one need only confirm a normal visual acuity.

COL Ranadive: Paragraph 5, TB MED 279, and paragraph 1-6, AR 40-46, provide the present guidance for medical surveillance of laser workers. The latter states:

1-6. Medical surveillance. a. Personnel to be examined. An individual whose occupation of assignment may result in a significant risk of exposure to potentially hazardous levels of optical radiation shall have a preplacement medical examination, a termination of employment examination, and be included in an occupational vision program. The following types of individuals are considered in this category:

(1) Those individuals routinely using lasers in any RDT&E effort.

(2) Certain laser equipment, such as tripod-mounted, hand-held or airborne laser rangefinders, designators, or illuminators may be determined to present a sufficient hazard to operators and maintenance personnel that such personnel may be required by The Surgeon General to be examined. The warning page of the technical manual for each laser device will indicate which types of user or maintenance personnel should be examined.

(3) Maintenance personnel routinely working with laser rangefinders, illuminators, or designators.

(4) Operators and maintenance personnel routinely working with engineering laser transits, geodimeters, and alignment devices which have a radiant power output exceeding 1 milliwatt.

b. Examination requirements. The medical examination shall follow the procedures in TB MED 279.

c. Examination of personnel known or suspected to have been injured by lasers. Personnel who are known or suspected to have been accidentally exposed to levels in excess of applicable laser protection standards shall be examined as soon as possible following such exposure. Personnel working with lasers or other high intensity optical sources who complain of persistent afterimages or other visual disturbances should be examined.

1-7. Requests for assistance. Requests for technical assistance from USAEHA in evaluating hazards from lasers and other high intensity optical sources should be directed through appropriate command channels per AR 40-4 to HQDA (DASG-PSP-E), WASH DC 20310.

COL Ranadive: Dave (Mr. Stiney), will you please address the concept of risk applied in terms of selection for detailed examination.

Mr. Stiney: The number of individuals routinely using lasers in an RDJE effort is probably now on the decline. There are fewer involved in laser research but perhaps more in test and evaluation, especially if one includes a test such as the Fort Hunter Liggett operation.

The second category, "certain laser equipment ... determined to present a sufficient hazard to operators. ..." has, as yet, never been applied. This second high-risk category was simply an attempt to establish a leverage on program managers (PM's) developing new laser hardware. We assumed that if they did not incorporate enough safety features to protect the eye of the operator, then we could inform the PM that all the operators of his equipment would have to receive eye exams. The developers fear such a requirement; hence, it has never been necessary to apply it.

The next high-risk category, "maintenance personnel," is very important. This is currently enforced and it is the most complied with. Everyone in maintenance has a certain MOS, and almost all laser maintenance training for those MOS's is conducted here at Aberdeen Proving Ground, so that preplacement exams on a routine basis are performed here at the beginning of every class.

The last high-risk category, consists of just a few people in the Corps of Engineers. This requirement was originally inserted because the operators often stared at a CW laser source, and we were concerned about the potential delayed laser visual effects.

COL Ranadive: Fine! From your standpoint are there any specific subgroups within those just reviewed, which you would want to separately consider for fundus photography or other specialized testing.

Mr. Stiney: Although the summary statement No. 3 of Dr. Jengroth states that epidemiology is not the purpose here, one of our primary considerations in retaining the RDJE personnel in this "high-risk" category was to provide a continuation of epidemiological data now in the records. Since these RDJE workers are most likely to be exposed chronically over a long period of

time, we are in a better position to field a future legal, congressional, or executive inquiry such as: How do you know for certain that laser workers are not really developing delayed effects? We could then answer that. We have followed this group of perhaps one thousand "high risk" personnel in the Army by monitoring them for 20 years and we have been unable to detect any statistically significant changes. As far as the highest risk group - those most likely to be injured - I think this group will be largely composed of maintenance people. They have the highest risk.

COL Ranadive: Very well, there is no reason to change the existing requirements.

Mr. Sliney: I agree.

COL Tredici: These groups are small, anyway.

Mr. Sliney: Many of the aforementioned workers already have baseline fundus photographs, anyway.

COL Whitmore: I think the principal point of paragraph 1-6c on accident situations should be that an immediate examination following a suspected exposure is imperative.

MAJ Mathewson: Can we clarify the requirements for the personnel participating in an Occupational Test and Evaluation Agency (OTEA) type of operation. They are not research and development personnel, but are participating in a form of that test and evaluation; e.g., the 900 to 1,000 involved at Fort Hunter Liggett should not have had these examinations since they are not "routinely" using lasers.

COL Ranadive: Those exams are the ones to stop. The question I have is how were these exams ever justified under the current Army policy? How do we stop this abuse of medical resources?

Mr. Sliney: The staff performing the tests actually requested even more extensive testing.

Mr. Lyon: Maybe there should be a section in the regulation that says who should not to be examined.

MAJ Mathewson: Up until now, if the local medical facility desired to test a larger group or test more exhaustively than required by regulation, they were allowed to do so. If the local commander "ran scared," he would over-prescribe testing.

COL McDermott: The wording in paragraph (1) states: individuals "routinely" using lasers in RDTE operations. Most field test personnel are not routinely using lasers. They are selected for a specific test, finish the test, and then depart. So why do we have such a requirement?

Mr. Sliney: This "TE" requirement was for TECOM permanent staff as opposed to OTEA or other one-time test personnel.

COL McDermott: Why were the 900 examined at Fort Hunter Liggett?

Mr. Sliney: I do not know. We would not have recommended such an effort. No such eye tests were done in similar field tests prior to that.

COL Ranadive: We need to determine some way to stop this, since we all agree that it should be stopped.

COL McDermott: Let me present an example of how these surveillance tests lead to trouble. We currently have a congressional inquiry as a result of a laser test that was performed in Europe in 1972. One individual involved now reports "degraded" vision. I do not have any idea what that term means. He applied to the Veterans Administration for compensation. It was turned down. He then wrote to his US senator. The senator then wrote The Surgeon General as well as the Veterans Administration. The whole basis for his complaint was that he was given a pretest; but because his father became seriously ill at the time that the posttest was due, he went home for several weeks, and then returned to his unit in Europe missing the posttest. In his discharge physical, his visual acuity was better than his pre-induction physical visual acuity. But his whole contention was: If it was so serious that they gave me a pretest but I didn't get a posttest, my degraded vision is because I didn't get the posttest. We live with such situations every day, but I understand that elimination of needless pretest examinations may help to reduce needless inquiries. In this incidence, he was not "routinely" exposed to those lasers; he was using one in a 5-day test and that is not "routine."

Mr. Sliney: Any unwarranted vision testing should be avoided to reduce the probability of unduly psychologically sensitizing the tested individuals to laser ocular effects. As it is now, the laser is a sufficiently advanced technology which most field users do not fully understand. Thus, when any visual change is later experienced, they have tendency to relate it to laser work. I have frequently fielded inquiries by soldiers who had experienced refractive changes in their vision and were worried that it was the result of working with lasers.

COL Ranadive: To summarize, the "high-risk" category receives the full exam upon assignment (i.e., at entrance), at termination, and when suspected of being exposed to a laser. Is this asking too much?

CAPT Blaise: Basically, a slit-lamp examination would be performed only on personnel working with a laser that would cause only external burns, which follows the ANSI Z-136.1 requirements. Those people in high-risk environments, specifically those working with Class 3 and Class 4 lasers are required by ANSI to have the standard examination that we talked about this morning.

COL Ranadive: Mr. Sliney, you mentioned some problems with following the ANSI Z-136 standard.

Mr. Sliney: The problem arises largely if one follows the ANSI Z136.1 hazard classification scheme. One can interpret that every laser rangefinder and designator operator should receive a fundoscopic preplacement exam. I argue that because these lasers are designed to protect the operator, he is the one least at risk; whereas, the general assumption underlying the ANSI requirements is that the individual is working around an open laser in a laboratory or in an industrial setting where clearly one is potentially exposed to that radiation. Remember that these difficulties which we have had with applying the ANSI Z136 requirements to our applications was a primary reason for having this symposium. A second goal was to produce a document from these proceedings to aid members of the ANSI Z-136 committee who are anxious to update their requirements. Therefore, we should emphasize what is best - both scientifically and medically - and then provide our opinion.

COL Tredici: I understand that they are interested in reducing their requirements.

Mr. Sliney: Exactly.

COL Ranadive: We therefore conclude that our present guidance adequately identifies the high risk group. And paragraph 5b of TB MED 279 (below) is the applicable examination for high-risk preplacement and termination exams:

5b. Examination Requirements. The medical examination shall be performed by an ophthalmologist, and shall include --

- (1) Recording visual acuity with correction (if below 20/40, check for improvement with pin-hole or \pm 0.50D spheres and 0.25D X-cyl).*
- (2) Dilating pupil and examining fundus carefully.*
- (3) Photographing or carefully describing or drawing any lesions seen.*
- (4) Performing slit lamp examination if the individual is potentially exposed to infrared or ultraviolet laser radiation.*

CAPT Blaise: This examination protocol is virtually the same as ANSI Z-136.1.

COL Tredici: The protocol is not bad. An ophthalmologist will perform three of those requirements on almost everyone examined and the fourth item on one out of every six patients, anyway.

COL LaPlana: Over the years since these exams have been carried out, how valuable was this? Has this ever helped one individual or ever provided one bit of significant epidemiologic data?

Mr. Sliney: This examination program has been useful only for the negative findings. With many people overly worried about lasers, because of the concern for exotic new effects, you can now say that, although we have been examining all these workers for quite a few years, we have found no positive findings. Thus we believe our protective procedures and policies are adequate. That statement alone is worthwhile.

COL Tredici: We have 10 years of records that show no injuries.

COL Ranadive: Secondly, should these exams be performed periodically?

COL Tredici: This full exam is not even necessary at termination. If the individual has not complained, one need only check visual acuity.

Mr. Sliney: There is a periodic vision test for this high-risk group using an Ortho Rator.

LTC Pitts: Current regulations require screening of these laser workers every year. This is part of the occupational vision program.

COL Tredici: The Air Force eliminated the periodic tests and we have not encountered any problems. Patients will come in if they think they are having a visual problem.

LTC Pitts: Under the normal occupational vision program, all who work in eye hazardous areas received a vision screening every 2 years, but the laser worker remains on a 1-year cycle. The Army may wish to reconsider this annual requirement.

MAJ Mathewson: Should we not perform funduscopy at the termination exam? People may not know they have been injured or exposed and this exam would help us.

COL Ranadive: Dr. Tredici is saying that since we are interested in the functional aspects we should test visual acuity and examine function, but not necessarily examine the fundus. What I understand--based on what I have heard in these 2 days--is that a worker may have spent 20 years (or a civilian, 35 years) in the Army when he reports for his termination examination. His visual acuity may be very good, but a fundus exam could narrowly suggest an acute injury, and he could have developed lesions of the retina. But, what does that mean? We could only document that he has a lesion. What have we achieved? Have we helped him? I am not sure that we need to do that.

Dr. Dash: The point was raised before that there might be delayed effects such as cataracts. You could look to compare them with latent effects.

COL Ranadive: This could only be expected for certain specific types of lasers.

Dr. Dash: For a certain type of laser, if this is a possibility, it could be a very good epidemiological study, and it could be helpful in terms of liability at a later date. If the latent period were very long, it would be nice to have records on that particular individual's fundus appearance at the point of termination from service.

COL Ranadive: I am not sure that would be that helpful. The reasons are that one could claim a significant lens abnormality developed afterwards, and, secondly, an acuity screening should show significant effects at the time. The next phase would be a slit-lamp examination.

Mr. Sliney: Cataract is very common. I understand that there were several hundred thousand cataract operations in the USA last year. We will all develop cataracts if we live long enough! This is a different problem from retinal injury.

COL Tredici: If there were a small number and you could afford to perform a slit-lamp exam, it is but one extra step: dilating the pupil. That is the crux of the matter. If you can afford to dilate the pupil, you will clear up all problems.

COL Ranadive: I agree. The evaluation of the lens is one thing; the evaluation of the retina is another. Beyond this, all of us are interested in trying to obtain data on examinations for future epidemiological studies. However, if one sees an abnormal finding, what should one tell that patient? Have you not put that particular physician on the spot? This is a classical problem of patient psychology. Are we helping the worker to tell him every detail? Maybe something abnormal exists and, perhaps, he will come down with cancer, perhaps not. But are you doing him a favor by informing him about a detail that may worry him, when in fact it is not something to worry about?

CPT Stout: Is it not better to record a lesion even in the absence of a decrement in visual function? Are we not in a much better position to record a small lesion, since the patient's civilian practitioner may note it several years after the patient has retired and ask the patient about retinal scars? Of these two approaches I do not know which one is better.

COL LaPiana: Your argument would have validity if it were possible to tell from looking at those scars that they were laser injuries. But we cannot do that; all that can be said is that they are scars.

CPT Stout: But what will the patient do? Will he allege that it was due to work with lasers?

COL LaPiana: They allege that all the time, anyway.

CPT Stout: But if his functional test was normal when he left the service, that would reveal something.

COL Ranadive: If you find that visual acuity in the termination examination is normal, and he alleges laser injury anyway, the only thing that occurs is that the full fundus examination is postponed for 5 years.

CPT Stout: From the liability standpoint, have we abrogated some of our responsibility?

COL Ranadive: What is our responsibility? What can one do when one finds a lesion?

MAJ Mathewson: There is one other value in such exams. Most of those in this high-risk population leaving the service may well be entering the laser industry. Hence, there may be an advantage to examine this population. Blotches on the retina could be reported afterwards.

Mr. Sliney: It is important to remember: if you do not have functional loss there is no legal liability.

COL Ranadive: This is what I am saying!

COL Whitmore: Where in this do we task the individual for the reporting of that change? There has to be some responsibility on his part.

COL Ranadive: MAJ Mathewson, you are not talking in terms of an exposure that is cumulative, that should be monitored. I have not the slightest interest in terms of protecting the industrial employer. If he is not wise enough to evaluate the employee who has worked previously with lasers and take a picture of his fundus, that is the employer's problem, not mine.

COL LaPiana: Between the Army and the Air Force, we have 25 years of experience examining laser workers that are high risk, and the net results have been zero. One can argue that we learned something: that they are not being injured. Why then, with our resources and personnel so limited, should the exams be continued? Let's not do these exams!

Mr. Sliney: Well, could you agree that a limited group should be followed? Or do you think that should cease also?

COL LaPiana: I think we should cease it because Thomas Tredici proved it is not needed.

COL Ranadive: Let me say that some exams might be worthwhile. One would be a photograph of the fundus. Dr. Tengroth said that a central fundus photograph would be useful as a baseline for the high-risk group, where there is a greater possibility that an accident victim may come to the physician for a suspected laser injury. We have been doing this exam and it has not been that expensive.

COL LaPiana: With 25 years of experience, there is not one case in which this has proven to be of value.

COL Ranadive: The other question I posed was: How do we improve our ability to diagnosis a suspected laser lesion? How do we improve the training of optometrists and ophthalmologists to diagnose a suspected laser lesion? The other question is: How do we improve the speed of patient reporting?

COL Tredici: If you can handle this, fine; but if not, you cease the exams.

COL Ranadive: At some point when this group enlarges, it might be worthwhile to reevaluate this decision.

COL LaPiana: My only point is: I believe that we have reached that point, and we must reevaluate this program.

COL Tredici: But we have not really documented this program. If asked for the facts, we would have to start a new project until we had all the records. If we could pool the experience (the data) from all three services, then maybe we would have documentation to stand on.

COL Ranadive: But, what are you saying Frank (COL LaPiana)? We should not even dilate the pupil and examine the fundus? What if he had a lesion already?

COL LaPiana: If he has a significant lesion, it should show up on a functional examination at the entrance process. If our system works, then that functional deficiency will lead to a referral for an appropriate examination and diagnosis.

COL Tredici: All enlistees in the Air Force are dilated and receive a fundus exam at entrance.

COL LaPiana: The Army does not do that.

COL Tredici: The Army does not examine the fundus of all enlisted men at least once? The Air Force does this once because there are about 50 problems which are eliminated.

COL Whitmore: How do you feel about a patient with a parafoveal lesion that does not produce a functional loss, who later develops a loss and claims it to be a result of a laser exposure?

COL LaPiana: I think that if the function was normal when he came in and the function is abnormal when he leaves, then he has a service-connected disability. And for that he shall be compensated no matter what the cause.

COL Whitmore: Your proposal would be to ignore the question of a lesion entirely and be concerned only with function.

COL McDermott: That is the way the Veterans Administration would evaluate it. I am sure of this.

MAJ Mathewson: Six months after a laser lesion to the foveal area, can the patient not recover good vision?

COL Whitmore: I acknowledge this. You can have lesions which are horrendous in appearance with normal function.

COL Ranadive: We appear to be saying that a fundus examination is really irrelevant to the issue, and that a fundus examination for surveillance, preplacement, termination, or determination of disability is really irrelevant because a change in visual function is all that matters.

Mr. Sliney: I would argue for one exception to that. From the standpoint of accident investigation, you can understand more if a fundus examination is performed.

COL Whitmore: With regard to preplacement examinations, suppose you were to find a lesion which we suspect could later be activated, we would probably advise against assigning that individual to a laser occupation. Alternatively, if we find bad vision in one eye, which could not be corrected, he is basically monocular. We would recommend that he not be assigned to a laser field because he could be zapped in that one eye and blindness would result.

CAPT Blaise: This approach would be similar to the Navy's ionizing radiation program. A preplacement examination is performed before schooling (e.g., active duty people) and before employment (e.g., Civil Services employees). If any lesions such as vacuoles (subcapsular lesions which could be confused with ionizing radiation effects) are found, we disqualify those people.

COL Tredici: You would eliminate everybody.

CAPT Blaise: This is our approach. I could not sell the idea of testing only for visual acuity. I think the ANSI system is hazard specific. One looks for the hazard in the given areas based upon the wavelength that will cause that individual problem. The ANSI only requires of everybody a history and the visual acuity. The others tests are wavelength specific or hazard specific based upon the laser which that individual will use. Accepting only visual acuity for preplacement and not learning about what types of lesions are present for documentation at preplacement is unacceptable. I think we would not accept a person into a laser career field with a lesion in the peramacular area that could be confused with a subsequent burn from a laser. I am speaking only of high-risk individuals, not about people like the Marine Corps enlistee who is out in the field. That is a different group, requiring a different screening program. We should follow the ANSI approach. As Tom Tredici suggested, I would have no heartburn about the high-risk exams because this is a very limited group at preplacement and termination. Then, the Veterans Administration has documentation to evaluate later claims.

COL Ranadive: Since this really does not have a large resource impact now in the Army program, I would like to propose that we retain the present policy as it is.

COL Whitmore: We should eliminate photography and slit-lamp examination as a routine on termination.

COL Ranadive: What do you think Walt (Pitts)?

LTC Pitts: If these are performed in the beginning, then I would like to have that as an end point to say that injury did not occur.

CAPT Blaise: Why can't we use the ANSI wording? A termination exam is optional.

COL Ranadive: Are you saying that it is acceptable to perform a termination exam?

LTC Pitts: If we bother with the initial one, why not perform the termination?

COL Ranadive: The reason for the initial examination is to rule out preexisting pathology.

LTC Pitts: The reason for the termination exam is to document absence of a lesion prior to leaving the service and not after.

COL Ranadive: But we said that visual acuity was okay. If it was not, then the fundus examination is needed.

LTC Pitts: Then to me it appears that an initial visual acuity should suffice.

COL Ranadive: Not necessarily, since normal visual acuity can exist with some sort of lesion in the retina that can later be confused with laser effects.

LTC Pitts: What difference will it make whether this lesion occurred before, during, or after? You are interested in functional loss.

COL Ranadive: Based on the point of view of diagnosis, if somebody comes in with a suspected laser lesion and they did not know it existed before, it would be helpful to have the initial exam.

LTC Pitts: If a number of persons working with a specific piece of equipment suddenly develop peripheral lesions that were not present initially, then you would know to look at that piece of equipment, even though it was not functionally significant to the individual. In truth, however, no such finding has ever been made.

COL Ranadive: Yes, it helps the examiner at that time.

COL Whitmore: Consider the patient who was normal when he came in and has normal function when he leaves, but a fundus photograph shows there is a lesion present when he leaves. We still do not know that was a laser lesion.

LTC Pitts: The problem is that you would never be able to corrolate a lesion with a piece of equipment.

COL Ranadive: Everybody will agree that if an employee leaves a laser job with normal visual acuity and if 5 years later his visual acuity decreases and he develops a lesion that looks like a laser lesion, based on what we know about lasers, he cannot say that eye was exposed to a laser 5 years ago, because there is no such thing as latent retinal damage from lasers. If there is any doubt that we cannot defend that, we should take termination photographs.

COL Whitmore: An Amsler grid test should be added to visual acuity.

COL LaPiana: There is another point which should be made. Any fundus photograph covers only about 15 percent of the retina, the normal macula. We are not talking about taking a picture of the entire retina, which can not be done.

COL Ranadive: I mean a fundus examination, not a photograph on termination.

COL LaPiana: Are you talking about having indirect ophthalmoscopy with scleral depression on every laser worker before he leaves the Army? This is unrealistic!

LTC Pitts: I lean toward the concept of functional testing at the beginning and end, but not the fundus photography.

COL Ranadive: Then, at preplacement, we should not be doing the fundus examination at all.

COL LaPiana: One more thing. There are many abnormalities that can develop in anyone - forget about lasers - all varieties of sickle cell anemia for example. You name it. Everybody who comes into the Army, except for probably fliers, comes in with nothing more than a functional examination. Not one in a million examined in an AFEES receives anything approximating an effective fundus examination. So we already have a functional test basis for all other diseases that can affect the retina of Army personnel.

Mr. Sliney: Again, I remind you, the original rationale was to support an epidemiological study of a limited number of personnel.

COL Ranadive: Frank (LaPiana), you are explaining that a good fundus examination is very time consuming and requires considerable skill. Are you saying that an ordinary physician really should not even bother to examine the fundus?

CAPT Blaise: No, we did not say that, but an adequate exam requires an extensive period.

COL Whitmore: Frank is saying that, even with the examination of the central retina, one cannot rule out the possibility of the existence of other lesions.

COL LaPiana: Examination with a direct ophthalmoscope will not reveal 80 percent of the retina.

LTC Pitts: When we did the exam, we examined the macula and disc and then took a couple of quick scans to search for small lesions out in the periphery.

COL Whitmore: The probability is that those lesions that are missed in the periphery will not be functionally significant.

Mr. Sliney: Years ago, when developing some of this rationale, Dr. Walter Geeraets, an ophthalmologist who worked with Dr. Ham and is now deceased, said that he was really troubled by this medical-legal idea that you should inform the patient if you see lesions that do not show up on any functional examination. He would use the expression, "I do not want to make the man a psychological cripple." In other words, do not upset the patient about something he does not understand and which is probably no more significant than a freckle. So you save much exasperation for the ophthalmologist by not requiring this "fishing expedition."

COL Ranadive: If ANSI standards now require a preplacement fundus examination and if we were to drop it, do you think they will be convinced to drop it?

Mr. Sliney: They need documentation. They need a consensus developed. They are very close to that consensus amongst much of their own group. In fact the only committee members leaning towards fundus exams were the research ophthalmologists. Their reason was more epidemiological than any other.

MAJ Mathewson: A consensus may exist among the group that documentation may be available in the services, but not collated. To skirt the issue for the moment, of what is needed for the laser worker at high risk would it be appropriate now to discuss the ocular evaluation at the time of an alleged injury? This is one of the things I am interested in. It seems that the services have a broader obligation to the soldier than just the medical-legal one. If an injury exists, we should verify the laser and find out why it happened so we can prevent it.

COL LaPiana: None of us would argue with that.

MAJ Mathewson: I think we could sell this massive fundus photography, provided we take a really aggressive posture in pursuing the alleged injury.

CAPT Blaise: In the Navy, the person would be seen as soon as he or she becomes aware that there has been an accident. That person would be evaluated utilizing the same examination criteria that are given in the ANSI standard. If the lesion is followed with time, there will be certain characteristic changes that take place that will usually establish the approximate time of injury. I think there is a pretty general consensus that is the way to approach the acute lesion. The important thing is for the patient to be seen as soon as possible.

LTC Pitts: Army regulations require examination immediately after, or at least within 24 hours of, the accident.

COL Ranadive: I am not sure that our existing reporting system, in terms of detecting accidents, is bad. We must answer the question of replacement fundus examination.

CAPT Blaise: For those high-risk people in the Navy working with lasers that can burn the retina, we shall continue.

COL Ranadive: Yes, and the Air Force, for the time being, will continue with a very small group of high-risk personnel. The Army will continue with exams for the high-risk staff, but not for the persons in the field. I think that at some future date it might be worthwhile to evaluate the real value of fundus examinations in terms of evaluation of a laser injury and maybe retain only the functional test. But for the time being I think we will keep this requirement.

COL Whitmore: I think we should make a statement that the validity of the pre- and post-examinations are coming into question and be considered for deletion.

Mr. Sliney: Dr. Jim Hathway, the ANSI Z-136.1 Medical Surveillance Subcommittee Chairman, left me with some notes before he left. These are the chief points he wanted to make: He favored moving in the direction of just functional examinations, but there were two things which troubled him. These were chronic, long-term delayed effects, possibly related to blue light, which, if true, would be more related to employees working with xenon-arcs in the laboratory or related to UV-A or blue lasers, now strictly found in the research and development community and not even seen in test and evaluation. So the lingering question of critical importance is to obtain more knowledge about laser injuries. The military needs more knowledge as well, so as to avoid surprises when lasers are encountered in combat. That alone should suggest that we need to keep at least baselines on a small group with the highest probability of an accidental exposure. This would provide more useful information to the people at LAIR.

COL Ranadive: The question that still bothers me, though, relates to a laser injury. If someone has a laser injury, is there a treatment? And will you look at visual function, or will you look at the fundus? What good is it?

COL Whitmore: Well, first of all, depending on the nature of the lesion, it is questionable whether or not we have any treatment. In other words, in the acute phase some people might use steroids based upon limited information.

COL Ranadive: If you have edema, with no visual function change, would you treat or not treat? If the patient has a visual function change, what factors should influence the decision for treatment?

COL Whitmore: I think probably what we see in the fundus will determine this.

Mr. Sliney: It is also important for the clinician to distinguish a laser lesion from other pathology. There was an incident at a research laboratory where the amount of energy that apparently caused a lesion was not totally out of keeping with what we know from animal research, but it was surprisingly low to cause a hemorrhage. There have been a few cases which were followed in Britain and elsewhere which were originally thought to have been laser related and which later turned out to be, most probably, retinal microaneurysms. For all I know, there may be treatment for a spontaneous microaneurysm. Hence, one would want to be able to distinguish between a likely laser injury and symptoms which at first could be attributed to laser exposure but are not, especially if treatable.

COL Ranadive: Then we should retain the preplacement examination for the high-risk group. We must now discuss the usefulness of termination exams for this group. Does the Navy perform a termination examination of the fundus for high-risk groups? Does the Air Force do this?

CAPT Blaise: Both the Navy and Air Force perform the termination exams as part of the routine discharge physical for active duty personnel and for the research people as well. COL Tredici mentioned two cases in the termination appointments he had personally examined. He saw one laser detachment from the institution, and he had a finding in one preplacement examination.

COL Ranadive: I guess we shall retain the termination fundus examination also. But I believe that it is worthwhile to examine the value of it. It may be "CYA" at this stage of the game, but we are not willing to delete the fundus examination altogether.

CAPT Blaise: Is Dr. Hathway concerned about the medical-legal aspect of not using fundoscopy when one examines only function?

Mr. Sliney: He is not really concerned. The scope of the ANSI standard does not include the medical-legal aspect. The purpose is to develop more of an occupational health specification or epidemiological scientific specification. Everybody is troubled, quite frankly, about what the proper course should be. It is also obvious from this discussion that there are many who would take COL LaPiana's position. Yet, there are always a few who are worried about deleting a practice we have been following for nearly 20 years. They would hate to be proven wrong in 5 years when an unexpected delayed effect would begin to appear.

CAPT Blaise: How many people are in this high-risk group in the three services?

Mr. Sliney: Probably 2,000 to 3,000.

COL Ranadive: In terms of the number who require an examination each year, the numbers should be much less.

Mr. Sliney: Yes, most of those examined are maintenance technicians who are 3- or 4-year enlistees who enter the sophisticated course at Aberdeen Proving Ground, and the other segment is composed of scientists who are in the Civil Service. They will work for many years.

LTC Pitts: About 600 per year are examined at Aberdeen while going through the Ordnance School (the USAOC&S).

CPT Stout: The number of surveillance examinees have increasing at the rate of about 25 percent each year.

Mr. Sliney: I would not expect to see a continued expansion at USAOC&S.

LTC Pitts: We see preplacement exams only. We perform no termination exams there.

CAPT Blaise: Is there something we should lay out specifically about accumulating data on a triservice basis about laser injuries and followup to these injuries? Should we lay out some guidelines in terms of what data to gather for clinical information? The ANSI standard says what clinical data to collect in terms of what exam for what type of wavelength. The other needed data are from the engineering point of view: power, wavelength, etc.

Mr. Sliney: The accident scenerio should be recorded very quickly while it is still fresh in the individual's mind.

CAPT Blaise: One could collect the data that was reviewed by CAPT Wolfe yesterday; describe how the person was hit with what type of laser of a given power, etc. I think we need to come up with a standard reporting of laser exposure characteristics so it will make no difference if the Army maintains its own registry, the Navy maintains its own, or the Air Force maintains its own. Later, we would put all the facts together in composite by grouping all this data and have something that is reportable. We do not want everybody accumulating different information that is not uniform throughout the services.

COL Ranadive: About 18 months ago US Army Medical Department personnel were tasked to review methods for handling laser injuries encountered with laser use in training. One matter that concerns me is trying to determine just how many and the degree of severity of any laser injuries that have occurred and the issue of a registry. Department of Army Headquarters promptly tasked USAEHA. What is the status of the registry?

LTC Pitts: It's being maintained here at USAEHA.

COL Ranadive: It's being maintained at USEHA, but also I believe that the Letterman Army Institute of Research (LAIR), COL Beatrice's group, has involvement from the standpoint of pathology and the determination of data useful for research. Does anybody know the status of this tasking?

LTC Pitts: We are studying several approaches now. Dr. Lorretta Dash of USAEHA visited the Army Safety Center at Fort Rucker to determine the recording changes necessary for an incident registry.

COL Tredici: From the USAF experience of registries, the various regulations and forms become worthless without a system to transport the individuals to a central examining point if the intent is to follow the patient. Furthermore, a procedure must exist to first deduce an injury if it is to be followed. The followup is then where the major breakdown occurs. Funds must be available for a system as we have in Aerospace Medicine. Each flyer has a fund. When he has a problem, travel money is available to send him to us. Therefore, we have a perfect way to follow him. In our microwave repository we encounter this problem because we need to follow both enlisted men and flyers. All of the flyers returned and we have followed all of them. All the other people became lost in the system.

COL Ranadive: I really do not want to address the details of the registry at this point. We may wish to question whether the proper organizations have been tasked to do the assignments. Obviously, if we do something which is worthwhile, it ought to be done right; and if it is not being done right, how do we improve it? These issues can be addressed. The next question is whether it is worthwhile to have a triservice registry. We do have within the Department of Defense an organization called the Armed Forces Institute of Pathology, which is familiar with registries.

LTC Pitts: The Army Environmental Hygiene Agency has been tasked to draft a Technical Guide for optometrists, ophthalmologists, and occupational health physicians. In the Appendix of this Guide is a checklist for suspected exposure incidents for the optometrists/ophthalmologists to follow. They would fill in the blanks while the details are fresh in their minds to avoid missing data. We could envision a triservice Technical Guide on this subject.

CAPT Blaise: Some of this relies upon engineering input and is much beyond what ophthalmic specialists could provide. The power and wavelength must be collected by an engineering staff.

Mr. Sliney: We developed a prototype questionnaire at USAEHA approximately 15 years ago. The problem is that the incidents have been so infrequent and one never knows where the next incident will occur. When one explains this low incidence, there is resistance to create an Adjutant General's form.

COL Ranadive: We are now addressing the issue of how to improve the evaluation of the suspected laser injury.

LTC Pitts: The medical data need to be combined with the technical data at some point. Today we have two channels in the Army: technical and medical, which are separated and do not meet.

MAJ Mathewson: We can actually add a third channel: safety.

CAPT Blaise: For the Navy, all medical and engineering data are to be submitted to The Surgeon General's Office. I am sure that the Navy would be glad to accumulate whatever data the three services agree to in consensus, to achieve a uniform reporting.

Tom (Tredici) talked about the reporting system that is already in existence. I would favor adding the engineering requirements to the information requested in the ANSI Z-136 standard as the minimal information. Then minimum data should be collected on every case so we could follow it. Could that be done?

Mr. Sliney: I think we should update our TB MED 279 (to be TB MED 524) section on accident reporting by adding two more questions to ask the victim at the initial visit to the the medical treatment facility (MTF). As a rule, the important data to obtain while fresh are: the description of where and how the patient was situated, the nature of the exposure, and what laser the victim thinks caused the exposure. The name of the laser and perhaps its serial number should also be obtained.

CAPT Blaise: When the safety staff goes back to reevaluate the accident, they should record the data necessary to put the entire story together to correlate both clinical and engineering findings.

Dr. Dash: The regulations require that excepted accidents should also be reported, but they are not. They are not reported to the Army Safety Center data bank. The Safety Center has only one incident that has been reported in the last 7 years. That is the only data I have on a laser-related incident. This is a reporting problem.

COL Ranadive: Dr. Dash, let us try to clarify what we mean by reporting. The individual soldier reporting to the medical treatment facility is one step, then the medical treatment facility and all the safety officers report statistics of what happened.

Dr. Dash: Somehow we must train people to react to an incident in a particular way.

COL Ranadive: What is now happening? Review each situation and study what happened, study where the problems were and determine if we can address them. Do high-risk groups report suspected injuries? They do not.

Mr. Sliney: Only on two occasions have I heard about incidents long after the fact. The victims did not wish to report the incidents to superiors; but there are only about two of those in the Army, whereas there have been many such cases in industry and elsewhere. The victims often confidentially report by telephone to us because we are known in this field.

LTC Pitts: Even in the Army we do not receive official accident reports directly through channels. The safety officer called us directly in each alleged incident.

COL Rosenberg: In one case we received a call from an optometrist at Yuma Proving Ground who was concerned about what he saw in one patient. It was he who called in and began the chain of investigations.

COL Ranadive: Once again, the worker reported to the medical treatment facility. That is the first step. Can we agree that most victims will do that?

Mr. Sliney: Certainly, the victim will come in if any significant changes in visual function occur.

COL Ranadive: The next step is the ability of the medical treatment facility to determine if that change in vision is a laser injury.

COL Whitmore: That ability is enhanced if the individual comes in immediately.

MAJ Mathewson: Regarding the first step (getting the individual to the MTF), perhaps there is a real need to stress the importance of training the individual to know he must go to the MTF very quickly in order for us to make any decent estimate of what happened.

Mr. Sliney: Field personnel know that. We publish this need in every publication, e.g., in our little pocket-size booklets on "Questions and Answers" on laser safety. When we question field military personnel about whether they know what to do in the event of an accident, they say, "I know that we have to take somebody to the eye clinic immediately."

COL Ranadive: That is all we can do. But the next phase I think is critical. We must improve the MTF's ability to diagnose, etc.

COL Tredici: We have these requirements in the AFOSH standard. Remember, there will always be more incidents than accidents. First, there is an incident which is reported by the clinic. It is an accident only if it can be documented. An incident is not an accident, and reporting procedures should reflect that.

LTC Pitts: That is where our system is failing.

Dr. Dash: Even for a suspected accident--an incident--we should receive a report.

COL Ranadive: We are addressing two points. It is important that we receive information of incidents. I am also concerned about how to improve our clinical ability to diagnose suspected laser injuries. That remains a problem.

COL Tredici: The first problem is very simple. The supervisor must direct the victim to go to the eye clinic and the supervisor must make a phone call to safety or to the bio-environmental engineer who studies the incident and to the doctor who starts taking care of the patient.

COL Ranadive: Reporting is not the problem. The problem is to identify the 12 or 13 high-risk installations for laser training of either the optometrists or the ophthalmologists, if available, in terms of evaluation and perhaps some other aspects of laser injury. That is the kind of corrective measures I am talking about. Then it is up to that individual to talk to the safety officer, who in turn can talk to the supervisor, saying that it is absolutely essential to report to the doctor right away if you suspect an injury. It is not going to be done by the Department of the Army.

LTC Pitts: When we perform surveys now, we stress to the occupational health clinics the need to inform supervisors that incidents should be reported immediately.

Mr. Sliney: If an incident occurred in my laboratory, the first thing to go through my mind if the victim does not seem to have a reduction in function is, as a supervisor, "Oh gosh, the paper work! How much time shall we lose with this incident!" If the Army were smart, it would create a system such that a supervisor is not tied up in endless paper work and reporting. If it is very simple, then the supervisor will surely do it. From past experience as a supervisor, I would be very reluctant to report any nonserious incident.

COL Ranadive: Now you are coming to the next part of that equation: What could we be doing to encourage reporting of accidents? One thing may be to have a checklist form for the supervisor just to mark in a few key points. Then, the employee also has some degree of responsibility to get help.

MAJ Mathewson: Can the MTF do that? If the supervisor gets the employee to the MTF, let that be his responsibility.

COL Ranadive: It is the supervisor's responsibility; this is nothing new. If the victim is a civilian employee, it is the supervisor's responsibility to fill out certain forms for compensation purposes.

COL Rosenberg: The supervisor must notify, fill out forms, and explain the circumstances in which the accident took place. There is no way around that; that is part of life. We have a system in the Army Medical Department--the MED-16 telegraphic message--which is supposed to notify your office (OTSG) and my office (HSC) when things of unusual occurrence take place. Certainly, zapping somebody with a laser beam would fall under that heading. But you can hold your breath. It took them a month and a half to tell me a man died from herpes encephalitis. There was a dead body in this instance, and it took them 6 weeks to notify us!

COL Ranadive: You are talking about the reporting of occupational illnesses by a telegraphic method. This will be an education in terms of the preventive medicine community. The preventive medicine community thinks only in terms of occupational diseases. Anything else has been not really important. It will take time, and that we have. I am still concerned about education of the ophthalmologists in terms of laser hazards. We need a reference document to answer questions when somebody comes in saying "I was zapped by a G/VLLD!"

LTC Pitts: Dave (Slaney) and I talked about that aspect for the Technical Guide. One could find the type of laser, approximate distance with probable retinal injury, or whatever, to give the clinician a "ball-park" idea of what one should expect.

COL Rosenberg: Ophthalmologists get together annually or biennially I am sure. A lecture on this is in order.

CAPT Blaise: As I mentioned this morning, we need education even in the ionizing radiation protection program, which has been in existence for a long time. We are going to develop a further educational program for the people performing the exams in high-risk ionizing areas. Adding a laser examination could be part of this total educational effort. We feel we need training in the ionizing radiation protection programs because we are still weak on reliability and consistency of reporting.

LTC Pitts: Right now optometry and ophthalmology have separate educational programs on this. I would like to see a coordinated effort between the two. The same education and information is needed by everyone, and a system should be set up for referral, so that both the optometrist and the ophthalmologist are experienced in this area. Communication is essential.

COL Whitmore: Communication through some sort of regional division or organization could be established.

COL Ranadive: I agree. We have optometrists right now at certain installations, and Dr. Whitmore showed you the nearest ophthalmologists. I think we need quick reporting, education, and understanding. In the event an accident happens, the patient reports to the ophthalmologist on call, and this has to be understood by everybody concerned.

LTC Pitts: The system needs to be worked out. Right now it is too loose.

COL Ranadive: What you propose to do should be worked out between COL Whitmore, yourself, and COL Giroux. I think your proposal needs to be followed up. Is that acceptable?

Mr. Sliney: It may be useful for us to check very briefly with COL Whitmore and COL LaPiana while they are here about a summary table of clinical signs and symptoms which appears on page 896 of my book with Dr. Wolbarsht (Sliney and Wolbarsht, 1980). In this table we tried to summarize all of the likely clinical findings and relate them to different types of sources. We might be able to modify the table to alter the arrangement by wavelength regions and to identify what lasers would cause this finding or that. I learned of one error from the ophthalmologists that I must change, but the idea is that it focuses upon expected changes. It is not very involved so it could even go into some general eye care TB MED or whatever. I shall attach a draft diagnostic chart as an appendix to the proceedings of this symposium (Appendix F).

COL Ranadive: This is agreeable.

CAPT Blaise: That table is the same as ANSI Z136, except ANSI has rated down the wavelengths.

COL Ranadive: Yes, but I think we really need to go one further step in terms of naming the specific lasers instead of wavelengths.

LTC Pitts: This would give the clinician an idea about hazard distances.

COL Ranadive: We are familiar with information presented in the format for use in the emergency room. I think we need to provide that sort of document to the clinicians who potentially would examine accident victims.

The next major question relates to visual function tests, which seems to be the examination of merit. Are they adequate? Do we need to modify or improve them? If so, how? Secondly, as we are concerned about the quality of the visual acuity screening incorporated in the Army periodic physicals, do potentially high-risk individuals require separate occupational vision screening programs?

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PROCEEDINGS OF THE SYMPOSIUM OF MEDICAL (OPHTHALMIC)
SURVEILLANCE OF PERS. (U) ARMY ENVIRONMENTAL HYGIENE
AGENCY ABERDEEN PROVING GROUND MD W G PITTS ET AL.
1982 USAREH-25-42-0450-84

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LTC Pitts: The screening instruments used today were developed many years ago, and I would be surprised if there were not room for improvement.

Mr. Sliney: What does the Armed Forces Vision Tester--the AFVT--cost?

COL Whitmore: About \$950.

Mr. Sliney: In reviewing the current status of medical electronics, it appears to be characteristic that the medical profession is overcharged for newly developed instruments. Therefore, considering the evolving new technology of microprocessors, it may benefit the Armed Forces to develop a second generation Armed Forces Vision Tester. Perhaps we should encourage our respective medical R&D commands to develop a newer and better system. A new AFVT that simply employs new technology and does not improve upon the visual functional data obtained is probably not warranted. In alliance with the people in aviation medicine who might desire a dynamic visual acuity test, we might make some progress toward achieving a test with more reliable and complete functional data. If the Army, Navy, and Air Force were to underwrite the development, it could contribute to vision science and minimize the cost of the final instrument.

COL Tredici: That was the problem before. We knew there was a demand for about a thousand screeners in the Armed Forces. Therefore, there was no risk to the manufacturer.

COL Ranadive: As ophthalmologists, do you agree that we need a new screener?

COL Tredici: It is not the ophthalmologists as much as the vision scientists like Professor Wolbarsht and visual psychophysicists who would like to develop a new-generation screener.

COL Whitmore: The question is: How good does a screener have to be?

COL Tredici: The current instrument is about as good and reliable as you can expect. I have studied the new-generation, microprocessor-based, auto-test screeners and they do not offer a real improvement.

COL LaPiana: Have we heard any arguments from our distinguished vision scientists to lead us to doubt the adequacy of current screeners?

COL Tredici: We have not! Vision scientists often argue that the AFVT is not that good and one could test other functions, but then we always have had to bring them back to the reality that they are dealing with a very sophisticated laboratory environment and not the typical clinical setting.

COL Ranadive: I understand that, for routine screening of visual acuity, the Armed Forces Vision Tester is adequate if run properly. We must now resolve another question: Should we provide the ophthalmologists and/or optometrists who will be examining suspected laser injuries with an Amsler grid, such as the device demonstrated by Dr. Wolbarsht?

COL Tredici: We have the standard Amsler grid.

COL Ranadive: Do we need to provide further training?

COL LaPiana: Standard illumination may be desirable.

CAPT Blaise: Is there any merit in supporting the development of a flash Amsler grid, such as the prototype demonstrated by Dr. Wolbarsht? Is that more objective to identify a laser lesion?

COL Tredici: It is better.

COL LaPiana: However, you will waste too much time explaining the test to the average enlisted patient. Therefore, it is just not practical as a method of screening.

LTC Pitts: I agree. We should utilize the current vision testers, but we should also continue to evaluate new technology. The Army should support this effort, but not as a major development program.

COL Ranadive: If we need to continue to "look," we need to say so in writing to the Army Medical R&D Command with justification.

COL Tredici: Since we have not fully used the systems we have to their capacity, we cannot be sure that they are inadequate. If fully utilized for 2 years and a defect were encountered, we could justify support of a new development.

COL Ranadive: I understand at this stage that if someone from either an academic institution or a commercial concern demonstrates a new screener, we can listen; however, we are not likely to task the Army Medical R&D Command to fund a new project like that. Is this agreed?

COL Tredici: I agree, because I do not think you will see an improvement.

LTC Pitts: Only two problems exist with the current AFVT: Color plates fade very quickly and patients have difficulties with the depth perception test plates.

COL Tredici: The color plates are cheap and can be easily replaced locally as they are in the Federal supply catalogue.

LTC Pitts: Many people have difficulty passing the AFVT stereopsis tests.

COL Tredici: If they fail the test the first time, they should be referred for a professional exam. The screener should not dwell unduly on any particular test. There will be those who have phoria problems who will be needlessly referred, but it is still a good test of binocularity which we have never utilized.

LTC Pitts: All of the AFVT tests are performed in the Army.

COL Tredici: We do not really run through all of the tests because it does cause headaches. For the laser workers, the other tests will help and are already in the inventory.

COL Ranadive: I do not have any more questions. Does anyone have any comments?

COL Tredici: I do not think this is a hopeless problem. We have a good nucleus of most of the things we need to do if we were to apply them. We are dealing with an infinitely small number of occurrences, and I do not think we shall have a big problem. The big problem is the mass screening.

COL Ranadive: I agree that, to date, we have not had laser injuries that have been a problem. But now we are entering an era where every military person leaving the service will have had the potential for injury from force-on-force training. The chances are that no matter what we do, we shall see some laser injuries. My biggest concern is the Army Medical Department's ability to diagnose, identify, evaluate, and perhaps, treat these injuries.

Dr. Dash: Is it not essential in future field-testing situations to keep an exposure listing of the number of individuals, their MOS's, the time and the place of the test? You need these data for future study.

LTC Pitts: In force-on-force training, protection is provided; thus, anyone injured is anyone who does not follow instructions; e.g., takes his protection off.

COL Tredici: After you find that 30 people in a row have lesions, epidemiology could tell you where the problem is.

COL Ranadive: I am not sure that these data are needed, but they are always nice to have.

COL Rosenberg: It is not the time that it takes, but how you obtain the information.

COL Ranadive: It is extremely difficult. We are dealing with soldiers who have the amazing ability to crush a skull with a tank turret. I bet my last dollar we are going to get laser injuries when they start doing it, irrespective of doctrine, training, and all the care that we take.

COL LaPiana: It will be very obvious when it happens.

COL Ranadive: It will be obvious. My concern is that when they get to the medical treatment facility for treatment, we have to make sure that the medical treatment facility has the ability to handle those incidents in terms of diagnosis and, most important, treatment when possible and needed.

COL LaPiana: We must maintain the clinical information.

COL Ranadive: Exactly! We must think in terms of the history of these patients, as we may be looking at long-term effects.

LTC Pitts: There should not be large numbers of injured soldiers.

COL Ranadive: I am not talking in terms of thousands, because if that were to happen you and Mr. Sliney will be fired. Now I would like to close the symposium. I would like to propose the following actions: LTC Pitts shall look at surveillance policy, make the necessary wording changes, and forward it. I would propose that the three service consultants here look into concept of a registry (who keeps it, how to improve it, etc). I propose that since COL Whitmore has volunteered, he will study the long-term impact of laser injuries. I propose that USAEHA meet with COL Giroux and COL Whitmore to address the clinical training needs of the ophthalmologists and optometrists, beginning with those installations where lasers are being used the most. I think we need to get a message to the field that it is no longer necessary to evaluate troops who are participating in field tests, so that we do not create any more false positives.

I would like to thank all of you for participating in this symposium. Most importantly, when trying to formulate policies and improve the quality of programs in the past, there has often been poor coordination between the clinical side and the preventive medicine side. Many times there has been a misunderstanding of points of view and, to a certain extent, a lack of appreciation for the expertise that exists. As much as it took time away from your job, it was extremely useful. The triservice aspect is laudable. We are now entering an era in which Congress is encouraging the Department of Defense and the three Surgeons General to get together on common problems. This symposium has been very helpful. And it has also been helpful in terms of exploring these problems prior to their study by the civilian community, so that another group does not come up with totally ridiculous requirements that we have to follow. To that extent, I think this symposium has been very helpful, and I am going to try to propose another one that would deal with toxic chemicals. Thank you very much.

SUMMARY AND POSTSCRIPT

General.

On 8-9 September 1982 a symposium on ophthalmic surveillance of personnel potentially exposed to laser radiation was held at USAEHA. Approximately 40 personnel attended from throughout DOD and nonmilitary organizations. Following the close of the general symposium, a limited meeting of Office of The Surgeon General (OTSG), US Army Health Services Command (HSC), and the US Army Environmental Hygiene Agency (USAEHA) personnel was held to determine Army policy in this matter. COL M. Ranadive, OTSG, chaired the symposium and limited policy meeting. COL D. Rosenberg represented HSC. The thrust of the ophthalmic presentations revealed that ophthalmic examinations had significant limitations, that examinations following accidental exposures were of paramount importance, and that examinations of large populations were neither practical nor of real value. A complete review of examination requirements during the policy meeting revealed that a strict interpretation of the Army's technical bulletin on laser safety (TB MED 279) and Army Regulation (AR) 40-46 fulfilled the desired policy needs. Clarifying language would be added to TB MED 524 to reduce confusion about applicability to test personnel.

At the time of the symposium, AR 40-46, Control of Health Hazards from Lasers and Optical Radiation, 30 March 1974; TB MED 279, Control of Hazards to Health from Laser Radiation, 30 May 1975 (reissued as TB MED 524); and TB MED 506, Occupational Vision, December 1981, stated that personnel potentially exposed to laser radiation should receive preplacement and termination-of-laser-work ocular evaluations. Whenever a suspected or confirmed exposure of the eyes to hazardous levels of laser radiation occurs, an immediate ocular evaluation should be performed. In accordance with AR 40-418 (superseded by AR 40-400, Patient Administration, 1 October 1983), a MED 16 report shall be filed within 5 working days of the incident. The ocular evaluation shall be performed by an optometrist, ophthalmologist, or physician skilled in funduscopy and biomicroscopy (slit-lamp evaluation) of the eye. Those personnel receiving a preplacement ocular evaluation should be incorporated in an Occupational Vision Program and receive a biennial vision screening examination with a multiphasic vision screener (e.g., Armed Forces Vision Tester or Ortho-Rater).

Problem Areas.

At the symposium two problem areas were noted in detail.

The heavy reliance of the examination upon qualitative measures (e.g. slit-lamp and ophthalmoscopic examinations) rather than quantitative visual function tests (e.g., Snellen acuity, contrast transfer, color plates) leads to variation in findings and interpretations by the examining eye specialists. The subtle nature of lenticular changes possible from infrared (IR) or ultraviolet (UV) lasers and minute retinal lesions from visible and near infrared (IR-A) lasers may be indistinguishable from other natural changes in these structures or from changes induced by other

etiologies. Two installations had reported "possible laser-induced changes" in the eyes of soldiers. These findings arose from eye examination programs following field tests at Fort Hunter Liggett, California and at Yuma Proving Ground, Arizona. Most, if not all, of these preliminary findings were later judged to be either normal, brought about by causes other than laser radiation, or caused by laser exposure received prior to working for the Government. These initial diagnoses demonstrated a shortcoming of the ophthalmic examinations and the need for better training, instrumentation, and education in this area. Since this symposium, a substantiated laser-induced retinal injury did occur at Redstone Arsenal, Alabama.

The numbers of soldiers who could warrant receiving these eye examinations could drastically increase in the future, if two-sided tactical exercises with LRF and LD became common. Additionally, future combat might expose essentially all soldiers to potentially hazardous levels of laser radiation. Based on a liberal interpretation of TB MED 279, this could result in such a large medical workload that ophthalmic examinations could not be performed on even a fraction of those requesting them.

Conclusions.

It was concluded at the policy session that personnel routinely working in RDTE laboratories (e.g., Harry Diamond Laboratories, Army Night Vision and Electro-Optical Laboratories, and Redstone Arsenal) should continue to be included in an ophthalmic surveillance program. However, there again seemed to be no significant value in providing examinations of personnel involved in short-term test programs such as operational tests where significant numbers of military personnel would be involved, and protective techniques would be designed to greatly minimize the probability of exposure. The difficulties inherent in examining a large number of test personnel had been clearly revealed during the Fort Hunter Liggett test performed in 1981. This examination program initially indicated that a few alleged laser injuries had been detected during examinations. This indication later proved to be a false alarm and was probably due to the severe time limitations caused by the requirement to examine large numbers of personnel in a short period. After reviewing the decisions made at the 9 September 1982 policy meeting, it was determined that no change in Department of the Army policy had to be made. A strict interpretation of existing guidance in TB MED 279 and AR 40-46 was sufficient. No immediate recommendation for a policy letter was therefore required, although additional clarifying language was added to the draft of TB MED 524 (the successor to TB MED 279).

APPENDIX A

REFERENCES

1. AR 40-4, 1 January 1980, Army Medical Department Facilities/Activities.
2. AR 40-5, 25 September 1974, Health and Environment (revised 1 June 1985, Preventive Medicine).
3. AR 40-46, Control of Health Hazards from Lasers and Other High Intensity Optical Sources, 6 February 1974 with Change 1, 15 November 1978.
4. AR 40-418, 16 August 1976, Medical Statistical Reporting.
5. AR 385-9, 1 April 1982, Safety Requirements for Military Lasers.
6. AR 385-16, 1 December 1980, System Safety Engineering and Management.
7. AR 385-30, 18 November 1971 (revised 15 September 1983), Safety Color Code Markings and Signs.
8. AR 385-40, 1 September 1980, Accident Reporting and Records.
9. AR 385-63, 22 February 1978 (revised 15 October 1983), Policies and Procedures for Firing Ammunition for Training, Target Practice and Combat.
10. TB MED 279, 30 May 1975, Control of Hazards to Health from Laser Radiation (revised as TB MED 524, 20 June 1985).
11. TB MED 506, 15 December 1981, Occupational Vision.
12. ANSI Standard Z136.1-1980, Safe Use of Lasers.
13. AFOSH Standard 161-10, 30 May 1980, Health Hazards Control for Laser Radiation.

APPENDIX B

ABBREVIATIONS

AAH	Advanced Attack Helicopter
AEL	accessible emission limits
AFEES	Armed Forces Examining and Entrance Station
AFIP	Armed Forces Institute of Pathology
AFOSH	Air Force Occupational Safety and Health
ANSI	American National Standards Institute
APG	Aberdeen Proving Ground
AR	Army Regulation
BEE	bioenvironmental engineer
BUMED	Bureau of Medicine
CW	continuous wave
DAC	Department of the Army Civilian
DEQ	Directorate of Environmental Quality
DLS	Directorate of Laboratory Services
DOEH	Directorate of Occupational and Environmental Health
DRES	Directorate of Radiation and Environmental Sciences
EAOOM	Edgewood Area Officers' Open Mess
ED	exposure dose
ED ₅₀	ED at which a lesion is observed 50 percent of the time
ENT	ear, nose and throat
Er	erbium
ERG	electroretinogram
ESSLR	Eye Safe Simulated Laser Rangefinder
FBI	Federal Bureau of Investigation
FIST	Fire Support Team
Ga-As	gallium-arsenide
G/VLLD	ground/vehicular locator laser designator
HDL	Harry Diamond Laboratory
He-Cd	helium-cadmium
He-Ne	helium-neon
Ho	holmium
HRR	Hardy, Rand and Rittler
HSC	US Army Health Services Command
Hz	hertz
IAW	in accordance with
IOP	intraocular pressure
IR	infrared
IR-A	near infrared
IR-C	far infrared
LAIR	Letterman Army Institute of Research
LD	laser designator
LED	light emitting diodes
LRF	laser rangefinder
LSO	laser safety officer
LTD	laser target designator

MEDCEN	US Army Medical Center
MEDDAC	US Army Medical Department Activity
MILES	Multiple Integrated Laser Engagement System
MOS	military occupational specialty
MPE	maximum permissible exposure
MTF	military treatment facility
NASA	National Aeronautics and Space Administration
NIOSH	National Institute for Occupational Safety and Health
NOHD	nominal ocular hazard distance
OEHL	Occupational and Environmental Health Laboratory
OSHA	Occupational Safety and Health Act/Administration
OTEA	Operational Test and Evaluation Agency
OTSG	Office of the Surgeon General
PCS	permanent change of station
PM TRADE	Project Manager for Training Devices
PRF	pulse repetition frequency
RDTE	research, development, test and evaluation
RF	radio frequency
RPE	retinal pigmented epithelium
SEED	safe eye exposure distance
SSN	social security number
TADS	Target Acquisition and Designation System
TB MED	Technical Bulletin, Medical
TDY	temporary duty
TECOM	US Army Test and Evaluation Command
USAEHA	US Army Environmental Hygiene Agency
USAF	US Air Force
USAOC&S	US Army Ordnance Center and School
USAFSAM	US Air Force School of Aerospace Medicine
UV	ultraviolet
VA	visual acuity
VEP	visually evoked potential
WHO	World Health Organization
WRAMC	Walter Reed Army Medical Center
WSMR	White Sands Missile Range
YAG	yttrium-aluminum-garnet

APPENDIX C

AGENDA

Wednesday, 8 September 1982

0800-0830 - Registration, Administrative Announcements	
0830-0900 - Welcome to USAEHA, Commander's Remarks	COL Wangemann
0900-0930 - Chairman's Overview of the Problem	COL Ranadive
0930-1000 - Lasers in Use in the US Army	Mr. Sliney
1000-1015 - Break	
1015-1115 - Ophthalmic Effects of Lasers - Research Knowledge	Mr. Stuck (for COL Beatrice)
1115-1150 - Clinical Experience with Laser Accidents	CAPT Wolfe
1150-1200 - Discussion	COL Ranadive
1200-1315 - Lunch	
1315-1400 - Visibility of Retinal Lesions - Panel Discussion	COL Beatrice* Dr. Tengroth Dr. Ham Dr. Wolbarsht COL Gibbons*
1400-1500 - Laser Injury to the Anterior Segment of the Eye - Panel Discussion	Mr. Stuck Dr. Wolbarsht Dr. Zuclich
1500-1530 - Medical-Legal Aspects	Ms. Jane Norman
1530-1545 - Break	
1545-1630 - Limitations of Ophthalmic Examinations/Diagnoses, Medical Manpower Available--Panel Discussion	COL Whitmore LTC Pitts(for COL Giroux*)
1800-2000 - Beef and Burgundy at EA00M	

*unable to attend

Thursday, 9 September 1982

0800-0830 - Occupational Vision Programs and Recordkeeping	LTC Pitts
0830-0900 - US Navy Experience in Ophthalmic Surveillance	CAPT Blaise
0900-0930 - US Air Force Experience in Ophthalmic Surveillance	COL Tredici
0930-0945 - Discussion	
0945-1000 - Break	
1000-1050 - Visual Function Testing - Panel Discussion	Dr. Hedin LTC Pitts Dr. Zwick CPT Levine* Dr. Wolbarsht
1050-1115 - Discussion	COL Ranadive
1115-1140 - ANSI Z-136.1 Committee Position on Ophthalmic Examinations of Laser Workers	Dr. Wolbarsht (for Dr. Hathaway)
1140-1200 - Who Should Be Examined/When/How? With What Equipment? Panel Discussion	COL Ranadive COL Rosenberg COL Cutting COL Gaydos COL Beatrice* COL Tredici COL Giroux* CAPT Blaise
1200-1205 - Closing Remarks	COL Ranadive

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NOTE: A limited meeting of OTSG/HSC/USAEHA personnel was held from 1330 to 1500.

APPENDIX D

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APPENDIX E

SUBJECTIVE SYMPTOMS AND CLINICAL SIGNS: OCULAR INJURY FROM LASER RADIATION

Subjective Observations	Clinical Signs	Possible Lasers
1. Brilliant flash of light. No pain or snap. Some afterimage, then scotoma appears as afterimage subsides.	Anterior clear. Well defined retinal coagulation (thermal burn). Retinal lesion (blanched) position corresponds to point in visual field whence laser beam was directed and to scotoma. No skin involvement.	a. Ardon (488/514.5 nm) if blue, blue-green or green flash b. Nd:Yag (632.8 nm) if red or orange/red flash c. Krypton (531 nm) if green (587 nm) if yellow (647 nm) flash d. Dye laser any color possible, but most likely yellow or orange
2. Brilliant flash of light, often accompanied by an audible snap. Some afterimage, then scotoma (floating red may be seen if vitreous hemorrhage is present). Afterimage may be donut shaped or non-existent. Pain may occur, especially if lesion was severe.	Anterior clear. Retinal injury, with degree of involvement varying from a well-defined white, blanched lesion (minimal) to retinal edema, to subretinal hemorrhage, to vitreous hemorrhage. No skin involvement.	a. Pulsed Ruby (694.3 nm) if red flash b. Pulsed Nd:YAG (532 nm) if brilliant green flash and afterimage. c. Flashlamp-pumped Dye Laser - any color possible but most likely yellow or orange d. Alexandrite (710-800 nm) if deep red or purple flash and dull afterimage
3. Scotoma without light flash, or flash of light was barely visible or "weak." No afterimage. Often accompanied by an audible snap. Immediate scotoma (floating red may be seen if vitreous hemorrhage is present).	Anterior generally clear. Clear retinal injury present, with degree of involvement varying from a well-defined white blanched lesion (minimal size) to retinal edema, to subretinal hemorrhage, to vitreal hemorrhage.	Pulsed Nd:YAG or Nd:glass (1050-1064) if no light flash or green/greenwhite flash observed
4. Scotoma appears gradually several hours to 48 hours following afterimage caused by staring into brilliant light source (e.g., laser, laser-induced plasma, sun, or welding arc) for a period of minutes by overcoming natural aversion response to bright light).	Anterior clear. Retinal lesion (blanched area) typically about 200 um diameter in foveo-macular area. Appears several hours to 48 hours following light exposure classical signs of solar retinitis.	a. Searchlight, or arc lamp if white b. He-Ne if red light w/green afterimage c. Argon/Hg if blue with red after image d. Krypton (531 nm) if yellow, (547 nm) if red
5. Scotoma appears with rapid onset. Normally no visible flash of light, although a dull, barely visible, red light may immediately precede scotoma, with onset of pain at time of scotoma.	Anterior generally clear, but lens and vitreous clouding possible; deep retinal coagulation involving choroid. Lesion may be circular, elongated, or broken (caused by eye movements during exposure).	a. Q:Nd:YAG (1.064 nm or 1.313 nm if anterior involvement) b. Q:Yttrium (1.315 nm) if anterior involvement
6. Vision suddenly blurs, corneal pain may or may not be present. Popping sound likely at time of exposure; possibly a white/grey or bluish flash. Clouding may appear as late as 24 hours postexposure.	Lens opacity or mild clouding (anterior); retina normal; may be some corneal involvement (and pain).	Kr:Fl (308 nm) if lens involved
7. White or blue-white flash of light followed by intense pain (at cornea); sensation of "sand-in-the-eye;" lid closure or blepharospasm.	Corneal and conjunctival epithelium within the palpebral fissure absent or largely sloughed off. Corneal edema. In mild case the cornea re-epithelializes within 2-3 days.	a. Short-pulse HF or CO ₂ laser (2.7-3 um if HF) or (10.6 um if CO ₂) b. Df laser (3.8-4.0 um) total corneal involvement. c. Pulsed Holmium (2.06 um) or Er:YAG (2.94 um) if superficial corneal involvement d. Pulsed Er:YAG (1.54 um) or Er:glass (1.64 um) if deeper corneal involvement

The above chart was prepared by Mr. Sliney to illustrate what could be possible and is based largely upon literature reports of animal studies and accidents.

APPENDIX F

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